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Open File Report 5708

The Onakawana B Drillhole (OGS 85D), District of Cochrane: Report on Drilling Operations and Preliminary Geological Findings

1989

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MINES AND MINERALS DIVISION

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The Onakawana B Drillhole (OGS 85D), District of Cochrane: Report on Drilling Operations and Preliminary Geological Findings

by

R.K. Bezys

1989

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V.G. Milne

V.G. Milne, Director
Ontario Geological Survey

FOREWORD

The Paleozoic/Mesozoic Geology Subsection of the Engineering and Terrain Geology Section recently carried out an inventory of part of Ontario's indigenous hydrocarbon energy resources. This program included the investigation of peat, lignite and oil shale. At the same time, an inventory of conventional oil and gas resources was completed by the Petroleum Resources Section of the Ontario Ministry of Natural Resources. As a part of the study of the lignite and oil shale resources in the Moose River Basin, a deep drill hole was drilled in the James Bay Lowland at Onakawana, adjacent to the Ontario Northland Railway line.

The lignite deposits at Onakawana are well known with some of the lignite being mined for test purposes in the 1940's. Oil shale resources in the area, specifically the Long Rapids Formation, are not as well known, but were also intersected in the Onakawana B Drillhole. A previously undocumented lignite seam was discovered in this drillhole in the Mesozoic Mattagami Formation. This suggests that more resources are available at Onakawana than earlier reported. This drillhole also confirmed that the oil shale beds in the Onakawana area are considerably thicker than in other areas in the Moose River Basin.

As the rocks in the Moose River Basin are not well exposed, a considerable amount of new geological information on the Devonian and Cretaceous rocks in the basin have become available with this new drillcore.

V.G. Milne, Director,
Ontario Geological Survey

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MAPS

Paleozoic/Mesozoic Geology of the Moose River Basin
(in back pocket)

ABSTRACT

The Onakawana B Drillhole (OGS 85D), drilled in March of 1985 by the Ontario Geological Survey, provides a completely cored section through the Quaternary, Cretaceous, Devonian and Precambrian succession in the eastern portion of the Moose River Basin, northern Ontario. The hole is located 118 kilometres north of Cochrane on the Ontario Northland Railway line and is situated within the Onakawana lignite field. This hole was drilled to provide a new reference drillhole possesses continuous core; to obtain additional information on the Cretaceous lignite field; and to acquire more data on the Upper Devonian oil shale unit.

The Onakawana B Drillhole was drilled to a depth of 321 metres. Surficial deposits account for the upper 22 metres of the section, with the lower 16.5 metres represented by Quaternary age units. Fifty-five metres of the Cretaceous Mattagami Formation are present, which consists of interbedded dark organic-rich claystones and lignite. A new discovery in the Mattagami Formation is a 1.5 metres thick lignite seam not previously reported from that area in the Onakawana lignite field. This new seam, along with the re-identification of the two other previously defined seams in the field, suggests more lignite may be present in the Onakawana lignite field than previously thought.

The drilling of the Onakawana B Drillhole also confirmed that the Upper Devonian Long Rapids Formation (an oil shale) is anomalously thick in the Onakawana area (approximately 80 metres). Middle Devonian carbonate strata is represented by 163 metres of section from the Williams Island, Murray Island and Moose River Formations. At the base of the Paleozoic sequence, 6 metres of unusual, coarse-grained sandstone was present, which in turn was underlain by 7 metres of highly weathered Precambrian granitic gneiss.

THE ONAKAWANA B DRILLHOLE (OGS 85D), DISTRICT OF COCHRANE: REPORT ON DRILLING OPERATIONS AND PRELIMINARY GEOLOGICAL FINDINGS

by

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1.0: INTRODUCTION

In 1930, the Ontario Department of Mines drilled a deep drillhole near the Onakawana lignite field to provide additional information on the stratigraphical succession of the Paleozoic and Mesozoic rocks in the James Bay Lowland. This drillhole, known as Onakawana A, provided a complete cored section through the Quaternary, Cretaceous, and Devonian sedimentary rocks of the eastern part of the Moose River Basin. The drill log was frequently used as a standard reference section for geological studies and resource evaluations for the region. Unfortunately, over the years, the drill core was either lost or destroyed, effectively preventing the drill core from being re-logged with current stratigraphic nomenclature. As part of the Hydrocarbon Energy Resource Program (HERP), the Ontario Geological Survey drilled a second hole in 1985 at approximately the same site as the Onakawana A Drillhole, not only to obtain a continuous core to provide a new reference drill core, but also to obtain additional information on the lignite field and the underlying potential oil shales located there.

The Onakawana B Drillhole was completed in March 1985, and was entirely cored from the surface to the Precambrian: a total depth of 321 metres. The drilling was carried out by Longyear Canada Limited and was administered for the Ontario Geological Survey by Golder Associates (Eastern Canada) Limited who were responsible for the non-geological aspects of the program. The Ontario Geological Survey field representative was J.W. Sanderson

who also prepared the preliminary lithological log for the drillhole which was first published in 1985 (Sanderson and Telford 1985) and is recorded in this report as Appendix A. The drill site was located at latitude 50°34'24" N and longitude 81°29'10" W, approximately five kilometres west of the Onakawana railway siding, on the Ontario Northland Railway which joins Cochrane and Moosonee. The siding lies 118 km north of Cochrane and 91 km south of Moosonee (Figure 1).

This report first presents a synopsis of the geology of the Moose River Basin and early work done in the area. The geology of the basin is described in ascending stratigraphic order, starting with the oldest Paleozoic unit, through the Mesozoic, and finally into the Quaternary units (section 2.0). Major structural aspects of the Moose River Basin are also discussed in this section. Following this, the geological units encountered in the Onakawana B Drillhole are presented (section 3.0) and intervals of economic interest are discussed in section 4.0. Finally, a summary of conclusions derived from the drillhole is presented (section 5.0).

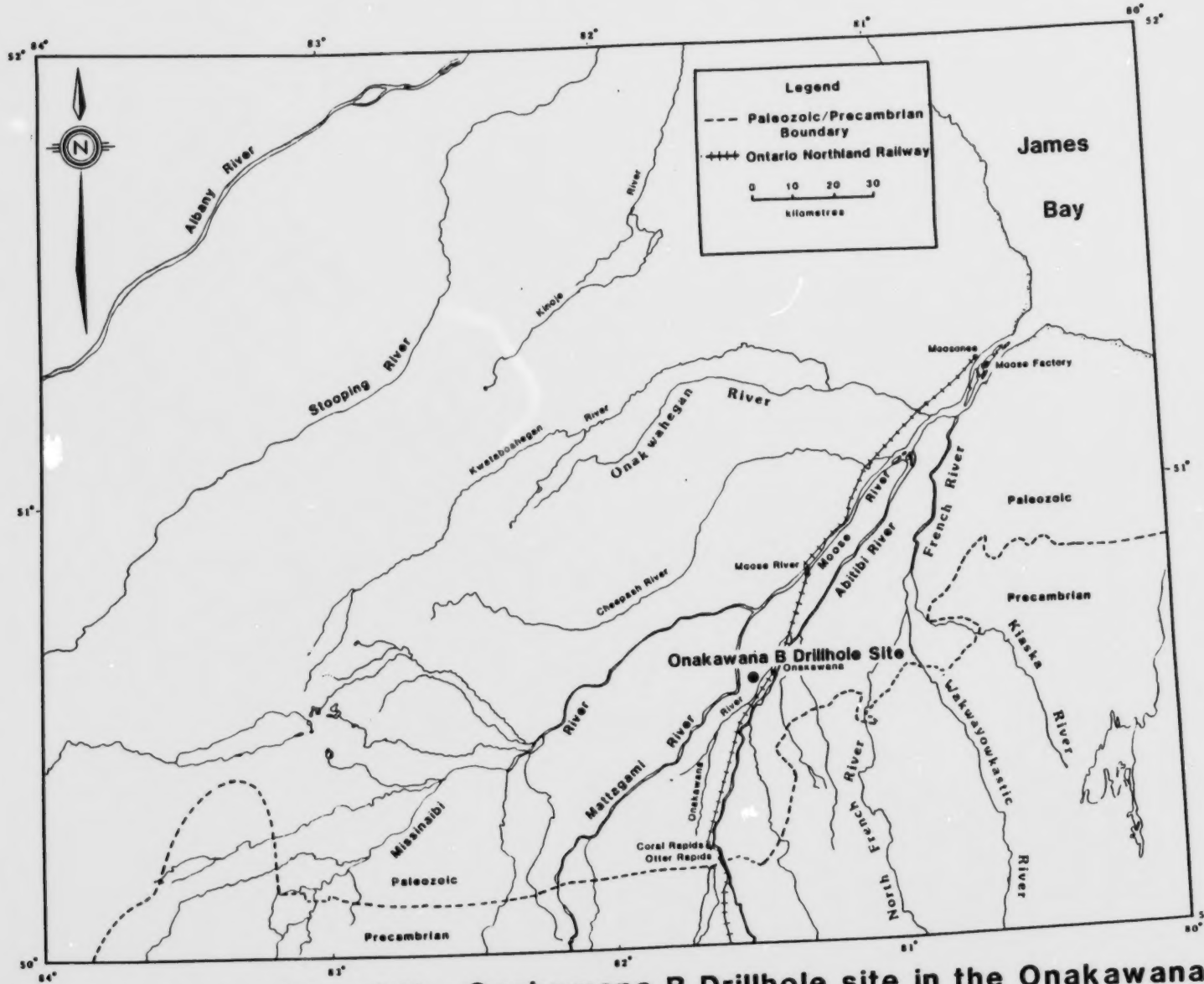

Figure 1: Location of the Onakawana B Drillhole site in the Onakawana area (modified after Price 1978, figure 1)

2.0: GEOLOGY OF THE MOOSE RIVER BASIN

Two intracratonic sedimentary basins, the Hudson Bay Basin (approximately 800,000 km^2) and the Moose River Basin (approximately 100,000 km^2), separated by the Cape Henrietta Maria Arch, on land, constitute the physiographic region of the Hudson Bay Lowland (Figure 2). The James Bay Lowland refers to the lowland surrounding James Bay and forms part of the larger Hudson Bay Lowland. The Moose River Basin occupies the physiographic land area termed the James Bay Lowland in Ontario.

2.1: Previous Work:

As large areas of the James Bay Lowland are covered by poorly drained muskeg and numerous lakes, information on the bedrock geology of the Lowland is confined to sparse river bank outcrops and geological drill holes. The first geological report on the area was by Isbister (1855) who wrote on the geology of the Hudson Bay territories. More detailed investigations were subsequently carried out by workers of the Geological Survey of Canada (GSC) and of the Ontario Geological Survey and its predecessors (i.e. the Ontario Bureau of Mines, the Ontario Department of Mines, and the Ontario Division of Mines). Robert Bell of the GSC produced 22 reports (1872-1912) on the geology of the area surrounding Hudson Bay, including aspects of the Devonian geology of the Moose River Basin. The first stratigraphic sequence for the Moose River Basin was attempted by

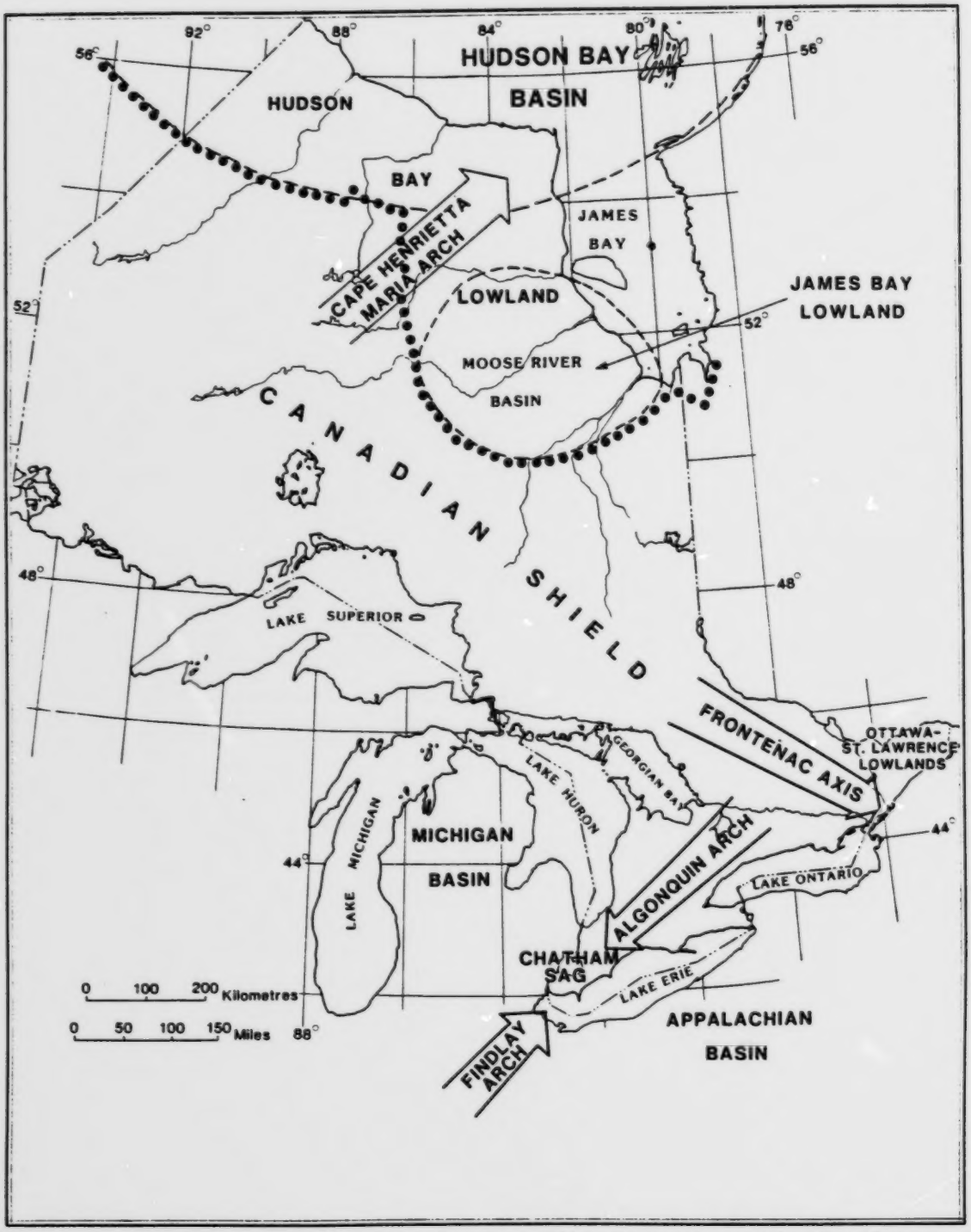

Figure 2: Sedimentary basins, physiographic elements, and structural features in northern Ontario. Basins are outlined with dashes and the lowlands are outlined with dots.

Savage and Van Tuyl (1919) who proposed a formation classification for the Paleozoic units. Other early workers, such as Williams (1920 a & b) and Kindle (1924), established the basic stratigraphic framework for the Devonian rocks of the Moose River Basin.

Geological reports by Dyer (1928) and Dyer and Crozier (1933) summarized the stratigraphy, paleontology, structural, and petroleum and lignite potential of the Moose River Basin. The later report also contained a summary of the first drillhole in the Moose River Basin to penetrate through the then known Paleozoic/Mesozoic sedimentary sequence in the basin (Onakawana A Drillhole). In 1953, Martison reported on the petroleum potential of the Moose River Basin. This report was a geological reconnaissance of the area and included a re-examination of the Onakawana A Drillhole. The geological log of the Onakawana A Drillhole is presented in Appendix B.

In 1966, Operation Kapuskasing was carried out by the Ontario Department of Mines. This was a mapping project of northeastern Ontario which included the southern portion of the Moose River Basin (Bennett *et al.* 1967). This report also included an inventory of drilling data in this study area produced by the Hydro-Electric Power Commission of Ontario. In 1967, Operation Winisk (Sanford *et al.* 1968) was implemented by the Geological Survey of Canada as a major regional reconnaissance mapping project. This study included all the Paleozoic rocks in the

Hudson and James Bay Lowlands (see also Sanford and Norris 1968; Norris and Sanford 1968, 1969). The first major study of Devonian stratigraphy of the Moose River Basin was reported by Sanford and Norris (1975) based on information gathered during Operation Winisk.

The Ontario Geological Survey in the past decade has carried out a number of surface and subsurface investigations of the Moose River Basin. These projects (e.g. Telford and Verma 1982; Russell *et al.* 1985) included assessments of the lignite, oil shale, and industrial mineral resource potential of the area, with a major emphasis placed on drilling programs (such as the recently drilled Onakawana B Drillhole).

A total thickness of Paleozoic/Mesozoic strata of less than 1000 metres overlie Precambrian basement rocks in the Moose River Basin. The southern boundary of the basin is marked by a distinct east-west trending, fault-controlled escarpment which separates the Precambrian uplands to the south from the swampy lowlands of the basin. Paleozoic units are dominant in the basin with only minor occurrences of Jurassic and Cretaceous sedimentary rocks. Quaternary deposits blanket the entire area. A summary of the Moose River Basin structural aspects and the Paleozoic/Mesozoic stratigraphy follows.

2.2 Structural Geology Aspects of the Moose River Basin

The Paleozoic units in the central portion of the Moose River Basin are generally flat-lying, except for beds affected by depositional or compactional dips over and around bioherms within the Paleozoic strata and over subsurface Precambrian highs. The basin's marginal areas, though, have experienced tectonic activity and the Devonian sequence has been disturbed by faults and small-scale folding. The southern boundary of the basin is truncated by an east-west en-echelon fault escarpment system, the Kapuskasing-Moosonee trend. Definite evidence that this escarpment is fault-bounded is found along the Missinaibi and Mattagami Rivers, with probable episodes of reactivation (Stoakes 1975).

Various lines of evidence suggest that several episodes of epeirogenic activity in the Hudson Platform area affected the deposition and subsequent burial history of the Paleozoic rocks in the Moose River Basin. The epeirogenic events are thought to have been associated with horizontal plate movements along the southeast and northeast margins of the North American plate. Sanford (1987) has illustrated the coincidence of the Hudson Platform epeirogenic activity with the plate movements during the Early to Middle Ordovician, Late Ordovician, Early Silurian, Early Devonian and Late Devonian. Further tectonism during the Middle to Late Jurassic included the emplacement of lamprophyric and kimberlitic intrusives in the Devonian strata in the southeastern corner of the Moose River Basin.

Three basement structural highs are presently known in the Moose River Basin: the Grand Rapids Arch, the Moose River Arch, and the Pivabiska Ridge. All trend approximately north-south and are located along the southern margin of the basin (Figure 3). The Grand Rapids Arch probably influenced sedimentation patterns, as indicated by the thickness and distribution of the Long Rapids Formation and overlying Cretaceous sediments. The lack of Paleozoic or Mesozoic sediments on the Pivabiska Ridge indicates its influence, whereas the influence on sediments by the Moose River Arch is not fully understood.

2.3: Paleozoic Stratigraphy:

Paleozoic rocks in the Moose River Basin range in age from Upper Ordovician to Upper Devonian, and are succeeded by Mesozoic rocks in the southern portion of the basin. The entire sequence is blanketed by Quaternary and Recent sediments. Paleozoic rock exposures tend to be sparse and widely separated, and are confined to the coast and along rivers that flow into James Bay.

The oldest Paleozoic rocks present in the Moose River Basin are the Upper Ordovician Churchill River Group and the Red Head Rapids Formation (Figure 4). In places, sandy basal clastic rocks directly overlie Precambrian granitic rocks, but the distribution and thickness of these clastics is not well defined and thus ages have not been assigned.

Ordovician units are present as outcrop in the Moose River Basin in the northern, western, and southeastern margins, but are

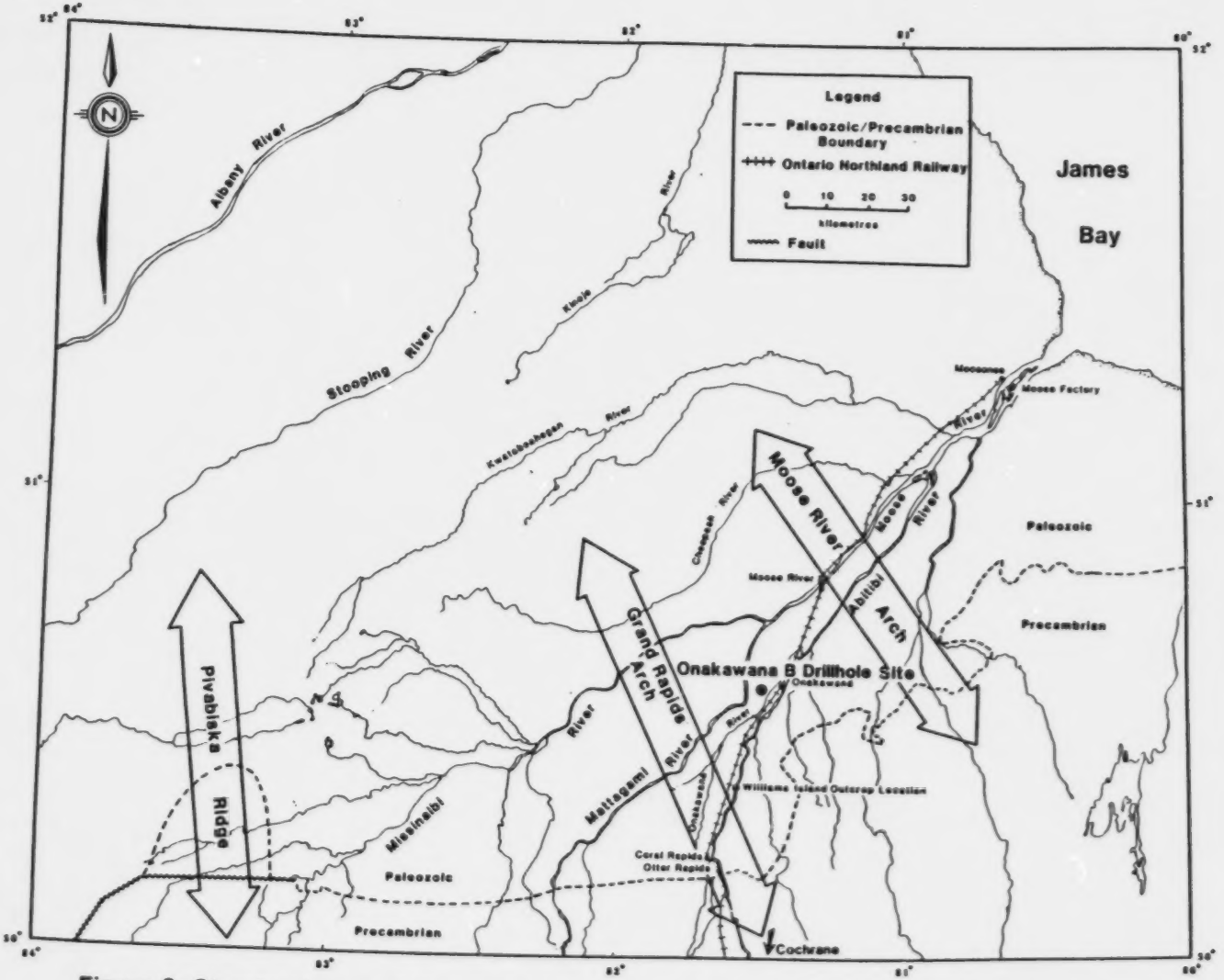

Figure 3: Structural map of the southern portion of the Moose River Basin indicating the Moose River and Grand Rapids Arches and the Pivabiska Ridge

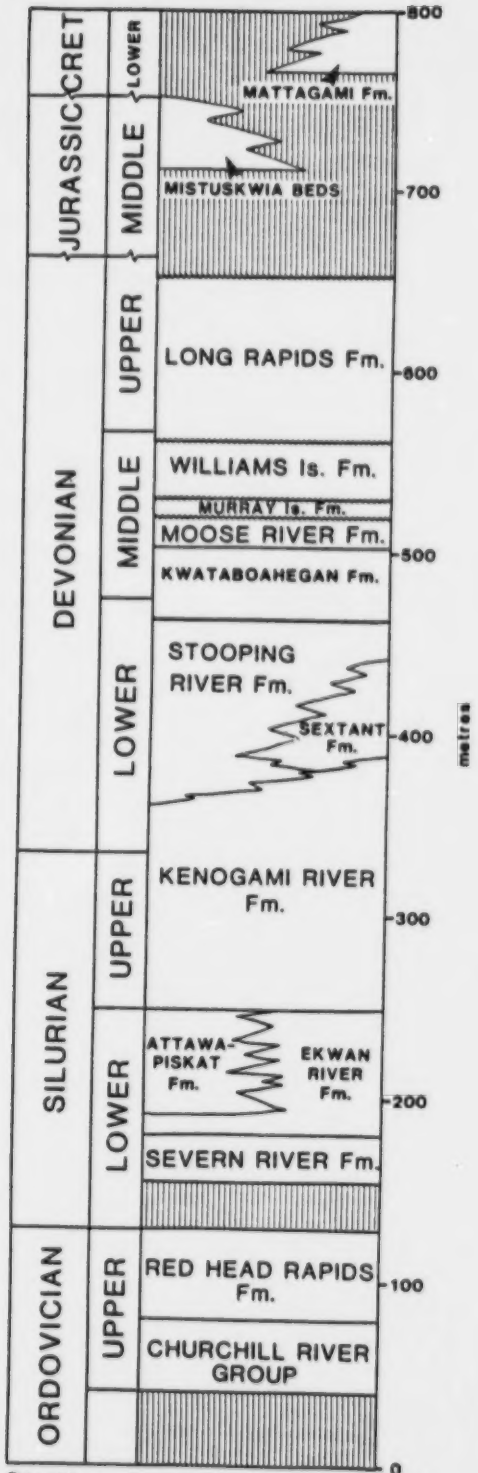

Figure 4: Stratigraphy of the Paleozoic and Mesozoic units in the Moose River Basin. Modified after Norris (1986 p.23)

poorly exposed (see map in back pocket). Units of probable Ordovician age have been inferred from subsurface records in the eastern margin of the basin (Sanford *et al.* 1968). The Churchill River Group consists of calcareous quartz sandstone, very fine-crystalline dolostone, bioclastic limestone, and cherty dolomitic limestone. The overlying Red Head Rapids Formation consists typically of dolomitic limestone, iron-rich dolostone, and microcrystalline dolostone with thin beds of anhydrite. These lithologies probably represent a minor transgression from the northwest over the Cape Henrietta Maria Arch (see Figure 2). A maximum thickness of approximately 80 metres has been recorded for these units.

Silurian outcrops are present in the northern, western, and southeastern margins of the Moose River Basin. Silurian units include the Severn River, Ekwan River and the Attawapiskat Formations, and the lower and middle members of the Kenogami River Formation. The Severn River Formation consists of various mixtures of lithologies including limestones, dolomitic limestones, and dolostones. The Ekwan River Formation consists of a well-bedded, skeletal and pelletoidal limestone and dolostone, whereas the Attawapiskat Formation consists of reefal carbonates. The combined thickness of these units can reach approximately 250 metres.

The Kenogami River Formation (which straddles the Silurian-Devonian boundary) consists of three informal members as follows:

- upper member: microcrystalline, brown and tan dolostone, with dolostone breccia (11-33 metres in thickness);
- middle member: red and green, gypsiferous mudstone, and dolostone (145-168 metres in thickness);
- lower member: fine-crystalline to microcrystalline dolostone with minor anhydrite (23-53 metres in thickness).

Contacts between the members are gradational. The Kenogami River Formation (the lower and middle members) is the only Silurian unit that is reasonably widespread in occurrence in the basin, and is found on the Kenogami, Pivabiska, and Coal Rivers.

Devonian age rocks constitute most of the Paleozoic stratigraphic sequence in the Moose River Basin (approximately 400 metres) and are represented by the following units (in ascending stratigraphic order): the upper member of the Kenogami, Sextant, Stooping River, Kwataboahegan, Moose River, Murray Island, Williams Island, and the Long Rapids Formations. All but the Sextant and Long Rapids Formations are marine carbonate units with significant evaporites in the Moose River Formation and shales in the Williams Island Formation (see map in back pocket).

The Sextant Formation consists mainly of reddish arkosic sandstone, but also includes varicoloured conglomerates, siltstones, shales and clays, with a maximum thickness of approximately 90 metres. It is present along the southern margin of the Moose River Basin and laterally wedges northward into and is overlain by marine carbonate beds of the Stooping River Formation. The Sextant Formation is usually considered to be

continental clastic beds, although Stoakes (1975, 1978) argues that the Sextant Formation consists of reworked coastal sediments.

The Stooping River Formation, correlative with the Schoharie, Bois Blanc and lower Onondaga Formations in the Appalachian Basin, consists of nodular to thin-bedded cherty limestone with minor dolomitic limestone and dolostone. It varies from 50 to 140 metres in thickness and is disconformably overlain by the Kwataboahegan Formation.

The Kwataboahegan Formation consists of massive to thick-bedded biohermal and biostromal limestones. The name, Kwataboahegan Formation, was introduced and defined by Sanford *et al.* (1968) to replace Martison's (1953) Upper Abitibi River Formation (see Figure 5 for terminology). The biohermal-biostromal nature of the Kwataboahegan Formation appears to be associated with topographic highs on the underlying Precambrian basement rocks. Away from these topographic highs, the unit is thinner bedded and bituminous. Generally, the unit is very fossiliferous with corals, stromatoporoids, brachiopods, and other invertebrates. The fossil assemblages are similar to those found in the Schoharie, Bois Blanc, Onondaga Formations faunas of the Appalachian Basin and similar to those of the Michigan Basin Detroit River Group. Its maximum thickness is approximately 30 metres.

The Moose River Formation consists of a non-fossiliferous brecciated limestone and dolostone, with gypsum beds and minor

anhydrite. The name Moose River Formation was originally introduced by Dyer (1928) but removed by Martison (1953) in favour of the term Middle Abitibi River Formation. Sanford *et al.*, (1968) and Sanford and Norris (1975) eliminated the Middle Abitibi River Formation and resurrected the term Moose River Formation (see Figure 5). The lithologies present in the formation reflect a regressive sea level phase, where the previously open marine platform conditions became restricted and environments conducive to evaporitic deposition were developed. The maximum thickness of this unit is 50 m in the Onakawana B Drillhole.

The Moose River Formation is disconformably overlain by the Murray Island Formation, a banded sequence of calcareous dolostone, limestone, and argillaceous limestone. The limestones represent a return to open marine conditions, and the brachiopod assemblage found in this formation suggest it is stratigraphically equivalent to the Onondaga Formation in the Appalachian Basin and the Dundee Formation in the Michigan Basin (Telford, in press). The Murray Island Formation was first defined by Sanford *et al.* (1968) because previous workers had assigned these strata to be part of either the Moose River Formation or Martison's Abitibi River Formation. The maximum thickness of this unit is approximately 15 metres.

The Murray Island Formation is disconformably overlain by the Williams Island Formation which Kindle (1924) described as a sequence of shales and carbonates exposed around Williams Island

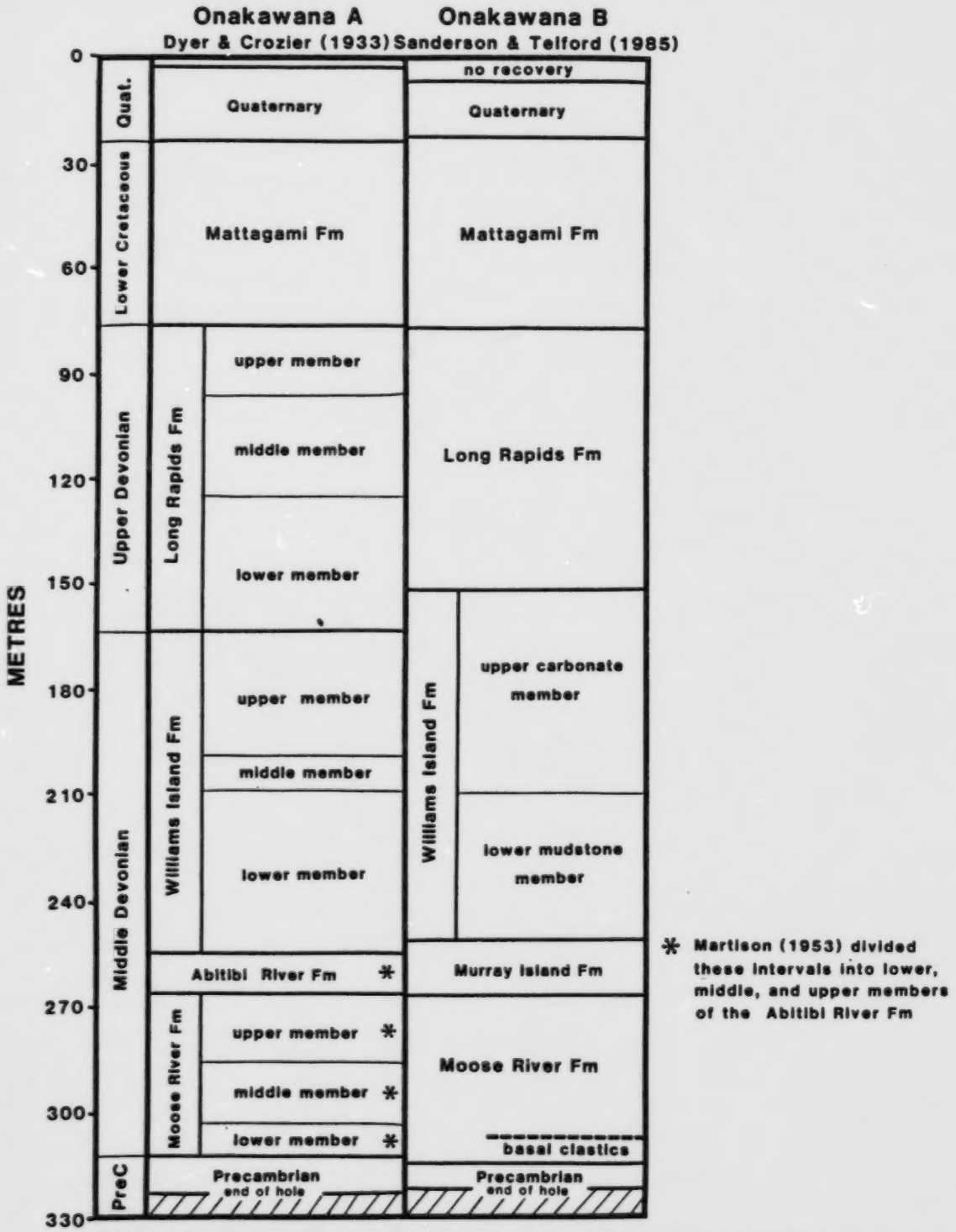

Figure 5: Comparison of stratigraphic nomenclature between the Onakawana A and B Drillholes, logged by Dyer & Crozier (1933) and Sanderson (1985), respectively

on the Abitibi River. The unit was divided into two informal members by Sanford and Norris (1975): a lower and an upper member. The lower member is dominated by grey shale with soft sandstone, gypsiferous shale, siltstone, sandstone, soft limestone and brecciated limestone (35-50 metres in thickness). The upper member is a thin-bedded, argillaceous limestone and calcareous shale, dolomitic limestone, oolitic limestone, brecciated, vuggy limestone, and dolostone (30-45 metres in thickness). The fossil assemblages found in the Williams Island Formation are very similar to those found in the Traverse and Hamilton Groups of the Appalachian Basin (New York State) and Michigan Basin (southwestern Ontario) which have been dated as Upper Middle Devonian (Givetian) (Norris 1986).

The upper contact of the Williams Island Formation with the Long Rapids Formation is observed on the east bank of the Abitibi River at Williams Island. The contact is sharp and disconformable. The Long Rapids Formation is the youngest Devonian unit present in the Moose River Basin and consists of interbedded brown-black shales, green-grey mudstones and shales, and carbonate nodules and beds. This formation appears to be correlative to the Kettle Point Formation in southern Ontario (see Russell 1985) and other Upper Devonian black shale units in eastern North America (i.e. the New Albany and Chattanooga) (see Cluff 1980; Kepferle and Roen 1981; Broadhead *et al.* 1982).

The Long Rapids Formation was first introduced as the Long Rapids Shale by Savage and Van Tuyl (1919) for a sequence of Upper Devonian shales exposed along the Abitibi River near Long Rapids and Williams Island. The average thickness of the unit is approximately 30 metres (Sanford and Norris 1975), but toward the eastern margin of the Moose River Basin, thicknesses of approximately 80 metres have been reported (from the Onakawana A & B Drillholes). Dyer and Crozier (1933) subdivided the unit into three informal members when logging the Onakawana A drillcore (a lower, middle and upper member). The lower member (up to 37 metres thick) consists of green-grey mudstone and shale, alternating with fissile black shale and frequent concretionary carbonate layers. The middle member (up to 30 metres thick) is a black fissile shale whereas the upper member (up to 20 metres thick) is a poorly consolidated green-grey clay and grey shale. The upper contact to the Mesozoic unit is not sharp.

Recent reviews of the stratigraphy of the Moose River Basin are outlined by Norris (1986), Sanford (1987), and Telford (in press).

2.4: Mesozoic Stratigraphy:

Mesozoic strata are represented by two units in the Moose River Basin; the Middle Jurassic Mistuskwia Beds and the Lower Cretaceous Mattagami Formation. The Mistuskwia Beds consist of unconsolidated calcareous clays and sands with minor gravel beds. They appear to be restricted to the south-central portion of the

basin. This unit has only been identified in drill core samples by palynologic analyses (see Telford *et al.* 1975; Telford and Verma 1982) and thus is not identified on the geology map of the Moose River Basin located in the back pocket.

The Mattagami Formation consists of unconsolidated clays, sands, gravels, and lignite. A considerable amount of exploration has been associated with the lignite horizons in the central portion of the Moose River Basin (see map in back pocket). The formation is interpreted to be the product of deposition in a highly constructive, possibly anastomosed, segment of a major river system which drained an extensive tract of the Canadian Shield (Try *et al.* 1984; Telford and Long 1986).

2.5: Quaternary Geology:

A sequence of Quaternary glacial and glaciolacustrine deposits, as well as Recent marine clays, peat, and muskeg blanket the Paleozoic and Mesozoic units in the Moose River Basin. The thickness of this Quaternary material is variable but can reach 200 metres. Identification of the Quaternary/Cretaceous contact can be difficult because of the unconsolidated nature of the Cretaceous and Quaternary sediments.

The Quaternary geology of the Moose River Basin is poorly known with the more recent publications on the area presented by Skinner (1973) and Shilts (1986). Skinner reported the presence of at least five distinct till sheets separated by non-glacial

and interglacial sediments as follows (from youngest to oldest):

- late- and post-glacial glaciolacustrine, marine, and terrestrial units
- Cochrane (Kipling) Till
- Friday Creek non-glacial sediments
- Adam (Matheson) Till
- interglacial Missinaibi Formation
- Till III
- intertill sediments II-III
- Till II
- Intertill sediments I-II
- Till I

The three pre-Missinaibi Formation tills, which recorded oscillations of a restricting ice margin, were deposited by ice advancing from the northeast. Separating the tills are glaciolacustrine sediments with south trending paleocurrents indicating blockage of the natural drainage to the north.

Till III is overlain by the Missinaibi Formation, an interglacial sequence of marine, fluvial and organic sediments. This formation is overlain by the Adam (Matheson) Till, the Friday Creek non-glacial sediments, and the Cochrane (Kipling) Till. These units are, in turn, overlain by Recent glaciolacustrine and marine sediments (deposited in Lake Barlow-Ojibway and the Tyrrell Sea, respectively). Isostatic rebound of the land in the Moose River Basin and the subsequent retreat of the sea halted marine sedimentation. Also, due to isostatic rebound, an

extensive series of stranded beach ridges formed parallel to the Hudson Bay shoreline. Extensive peat bogs and spruce forests near river banks have developed since then.

3.0 A SYNOPSIS OF THE GEOLOGY ENCOUNTERED IN THE ONAKAWANA B DRILLHOLE

3.1: Introduction

The following is a detailed examination of the geology encountered in the Onakawana B Drillhole as originally logged by J.W. Sanderson of the Ontario Geological Survey in March of 1985. The technical aspects of the drilling are presented in Appendix C.

3.2: Quaternary Geology (drill interval 5.5-21.9m):

In total, 16.4 metres of Quaternary deposits were encountered in the Onakawana B Drillhole. Core recovery was poor at the top of the sequence, but became progressively better towards the base. The youngest sediment is a marine unit, 1.2 metres thick, consisting of a clayey silt to a very fine-grained sand. This unit has a gradational contact with the underlying Cochrane (Kipling) Till. This 0.3 metres thick till unit has a 5% carbonate clast content in a sandy silt matrix. The next non-glacial unit encountered is the Friday Creek sediments (2.1 metres thick). This unit is followed by the Matheson (Adam) Till, which consists of a grey, silt-rich matrix with a 5-10% clast content. Clasts are predominantly carbonate and the unit is nearly 9 metres thick.

The oldest interglacial unit present consists of a clay, varved in some intervals, with silty partings and is 0.9 metres thick. This unit is underlain by another unnamed till, 2.1 metres

thick, consisting of a black, silty clay with a 5% clast content. Only three tills [versus five that are encountered elsewhere in the Moose River Basin (Skinner 1973)] are present in the Onakawana B Drillhole. The lower contact to the Mesozoic sediments is gradational over a short interval.

In the Onakawana A Drillhole, 22.6 metres of Quaternary deposits were logged. From Appendix B, it can be seen that a unit subdivision based on tills and interglacial sediments was not used. Instead, Dyer and Crozier (1933) identified the predominant intervals as soft, blue-grey marine clays (at the top) and black, plastic clays and sand with re-worked Cretaceous sediments at the base.

3.3: Mesozoic (Cretaceous) Geology (drill interval 21.9-76.8m):

The Lower Cretaceous Mattagami Formation is the only Mesozoic unit intersected by the Onakawana B Drillhole. The Middle Jurassic Mistuskwia Formation, located in the south-central portion of the basin, was not intersected in this hole.

The Mattagami Formation in the Onakawana B Drillhole consists of interbedded dark organic-rich claystones and lignite. In this hole, two major and one minor lignite seam are present. The upper seam (between drill interval 124' to 156.5'- 37.8m to 47.7m) is approximately 10 metres thick, the middle seam (between drill interval 177.5' to 200'- 54.1m to 61m) is approximately 7 metres thick, and the lowermost seam (between drill interval 210' to 215' - 64m to 65.5m) is 1.5 metres thick (Figure 6). The upper

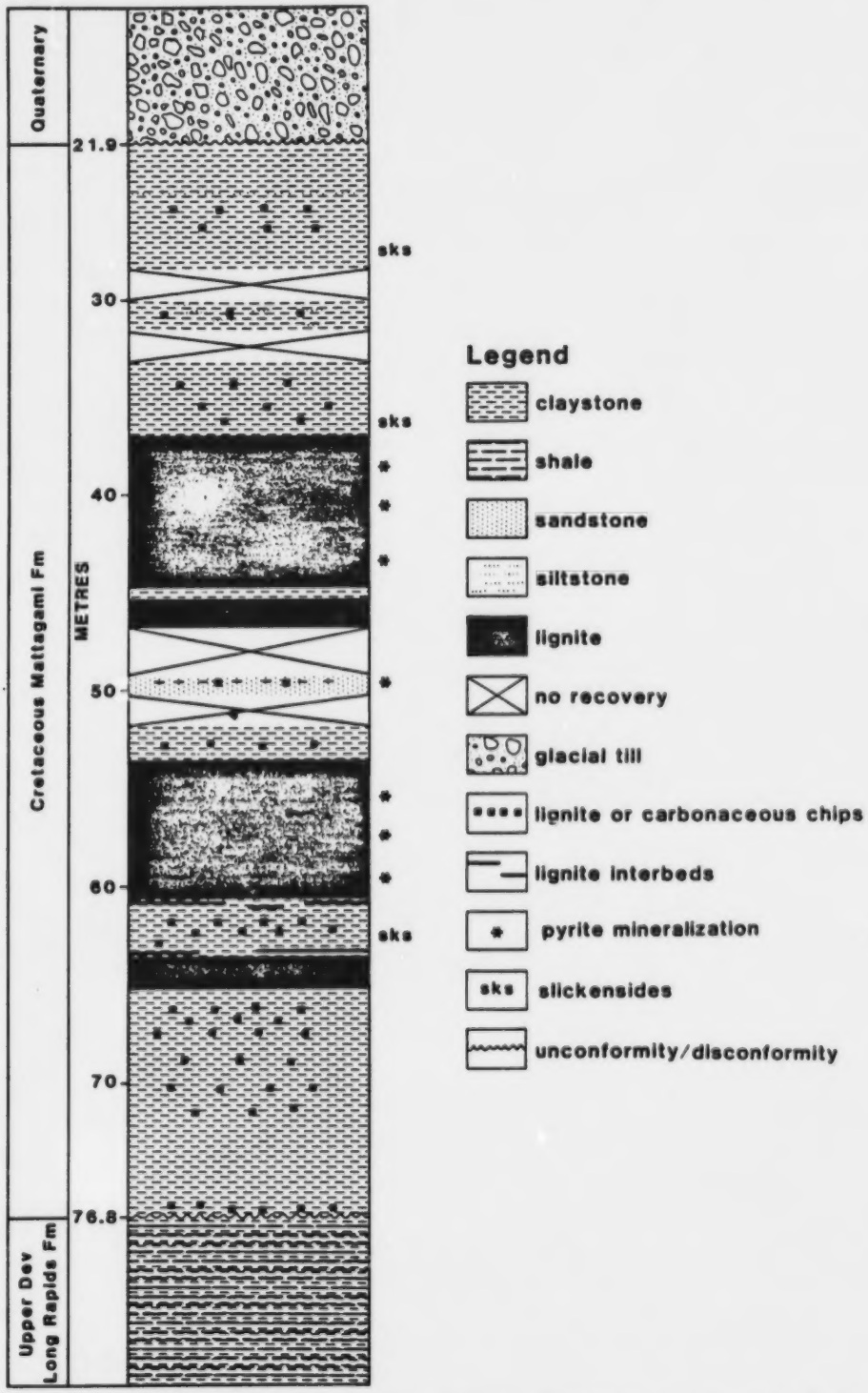

Figure 6: The Mattagami Formation (Mesozoic) stratigraphic interval from the Onakawana B Drillhole

seam possesses a 2' (0.6m) claystone interbed towards the base of the unit.

The lignite is a mixture of woody, peaty and earthy material, with the middle seam having more woody and peaty material than the other seams. The two thicker seams are separated by 6.4 metres of interbedded sandy clay, dark organic clay and white quartz sand. The middle seam is separated from the lowermost seam by 3 metres of interbedded lignite and claystone. Towards the base of the formation, the lithology becomes lighter coloured with light grey-brown claystones with dark grey interbeds.

In the Onakawana A Drillhole, the two thicker lignite seams were recorded, but the lowermost seam (1.5 m thick) was not reported. In this lower interval, an interbedded sequence of dark grey to black clay and lignite was identified by Dyer and Crozier (1933).

The lower contact of the Cretaceous Mattagami Formation with the Upper Devonian Long Rapids Formation is surprisingly not sharp, although it represents a major disconformity. This appears to be a result of the lower part of the Mattagami Formation being very similar in lithology to the upper portion of the Long Rapids Formation. The Mattagami Formation, in both the Onakawana A and B cores consists of light grey-brown claystone with some darker bands. The Long Rapids Formation consists of pale greenish-grey claystone and mudstone with thin bands of grey shale, which become more calcareous with depth. For the Onakawana B core,

palynological analyses (performed by P. Zippi, University of Toronto, 1985) were used to accurately locate this contact.

3.4: Paleozoic Geology:

3.4.1: Upper Devonian Long Rapids Formation (drill interval 76.8-151.6m):

In the Onakawana B Drillhole, 75 metres of the Long Rapids Formation was originally logged by J.Sanderson of the OGS (see Appendix A). In subsequent re-logging of the interval by Sanderson and Telford (1985), 79 metres of the Long Rapids Formation was identified. When compared to the 87 metres logged by Dyer and Crozier in 1933 from the Onakawana A Drillhole, a 7 to 12 metres discrepancy is noted. This difference appears to be related to the placement of the contact with the Williams Island Formation but may have been due to poor core recovery from the Onakawana A Drillhole. Bezys (1987) logged 81 metres of the Long Rapids Formation and was able to subdivide the unit into Dyer and Crozier's original three members.

The Long Rapids Formation, in both Onakawana cores, was subdivided into three informal members, an upper, middle and lower members. The upper member consists predominantly of inter-bedded mudstones and minor grey shales. The middle member is made up of black fissile shale, whereas the lower member consists of green-grey mudstone and shale, alternating with fissile black shale and frequent concretionary carbonate horizons. In the Onakawana B Drillhole, concretionary carbonate beds were evident

as calcareous concretions and nodules. Actual carbonate beds were difficult to discern. Fossil evidence was confined to bedding planes, consisting primarily of algal spore cases (*Tasmanites*) in the dark shales, *Lingula* shells (whole and fragments) along bedding contacts, and scattered shell fragments in calcareous shale and carbonate horizons. Fossil abundance tended to increase towards the base of the formation. From the Onakawana A Drillhole, the following specimens were retrieved by Dyer and Crozier (1933) and identified by E.M. Kindle and A.E. Wilson (in Martison 1953, p. 46):

Brachiopods:

Productella sp.

Lingula ligea Hall

Lingula nov. sp.

Leiorhynchus cf. *laura* Billings

Chonetes cf. *lepida* Hall

Ambocoelia umbonata (Conrad)

?*Styliolina fissurella* Hall

Conodont:

Polygnathellus cf. *curvatus* Ulrich and Bassler

Miscellaneous:

(*Tasmanites*) *Protosalvinia huronenis* (Dawson)

Crinoid stems

Appendix D lists conodont species identified from the Onakawana B Drillhole, with the bulk of the samples being from

the Long Rapids Formation. Species identified represent at least 6 of the standard Upper Devonian conodont zones, ranging from earliest Frasnian Lower ***asymmetricus*** Zone, to the middle Famennian Lower ***rhomboidea*** Zone. Work carried out by P.G. Telford (Ontario Geological Survey) and T.T. Uyeno and A.W. Norris (Geological Survey of Canada) has suggested that the Long Rapids Formation spans most of the Upper Devonian with the Middle/Upper Devonian boundary located near the base of the unit, and the Frasnian/Famennian boundary lying only 35-40 metres stratigraphically higher (Telford 1985, in press).

3.4.2: Middle Devonian Williams Island Formation (drill interval 151.6-250.4m):

The Williams Island Formation in the Onakawana B Drillhole was subdivided into two informal members (see Appendix A), an upper carbonate member and a lower shale member, with a total thickness of 98.8 metres. The upper member consists of 57.6 metres of predominantly brecciated limestone and mudstone/shale. The mudstones and shales are light green to grey in colour, calcareous, pyritic, and occasionally fossiliferous. The limestones are light-brown, grey to tan, sucrosic, fine to medium crystalline and thin- to thick-bedded. Limestone to mudstone ratio in the uppermost portion of the member is approximately 10:90, changing to 85:15 towards the base. Gypsum beds (up to 1 metre thick) appear towards the base of the member and are inter-

bedded with red-grey gypsiferous mudstone. The lower member (41.2 metres) consists of a dark grey, silty, calcareous mudstone with interbeds of thin, grey, plastic clay. Clay content increases towards the base, and the lower contact is sharp to the Murray Island Formation.

In the Onakawana A Drillhole, Dyer and Crozier (1933) subdivided the Williams Island Formation into three informal members as follows:

- upper member: (36.6 m) interbedded buff and grey porous and cavernous limestone and calcareous shale, brecciation is common,
- middle member: (9.8 m) red gypsiferous shale, grey calcareous shale and gypsum,
- lower member: (45.4 m) massive grey shale.

The total thickness of the Williams Island Formation in the Onakawana A Drillhole was 91.8 metres. Total thicknesses for the Williams Island Formation between the Onakawana A and B Drillholes are nearly the same, except for the presence of a middle member as defined by Dyer and Crozier. The middle member (gypsiferous shale) is actually the lower 9 metres of the upper (carbonate) member as described by Sanderson (1985) (Appendix A).

3.4.3: Middle Devonian Murray Island Formation (drill interval 250.4-266.1m):

In the Onakawana B Drillhole, 15.7 metres of the Murray Island Formation was intersected. As mentioned previously, this

unit was first defined by Sanford *et al.* in 1968, but in the Onakawana A Drillhole, Dyer and Crozier (1933) termed this interval as the Abitibi River Formation (11.3 m). Typically, the Murray Island Formation in the Onakawana B Drillhole is a light brown, very fine- to medium-crystalline, thin-bedded, fossiliferous limestone. Brecciation becomes more abundant towards the base of the unit. Abundant fossils include brachiopods and crinoids.

The Onakawana A Drillhole Abitibi River Formation (Murray Island Formation) interval is very similar to the above described sequence, except the top 4.4 metres of the formation was included in the Williams Island Formation by Dyer and Crozier (1933) (see Figure 5).

3.4.4: Middle Devonian Moose River Formation (drill interval 266.1-313.8m):

Dyer in 1928, first introduced the term "Moose River Formation", and Dyer and Crozier (1933) later subdivided the formation into three informal members after logging the Onakawana A Drillhole. Martison (1953) dropped the term "Moose River" in favour of the Abitibi River Formation and designated this interval as the middle member. The term "Moose River" was re-introduced by Sanford and Norris (1975) (see Figure 5).

In the Onakawana B Drillhole, the formation consists of 41.5 metres of unfossiliferous to sparsely fossiliferous limestone,

dolostone, brecciated carbonates, gypsum and minor anhydrite. The upper contact to the Murray Island Formation is sharp. Some scattered mudstone clasts are also present. The unit was not subdivided into three members, as it was in the Onakawana A Drillhole.

The base of the Moose River Formation is separated from the Precambrian basement by 6 metres of very coarse-grained, cream-coloured, arkosic sandstones (basal clastics).

At drill interval 1029.5-1053' (313.8-320.9m), a red, highly weathered granitic gneiss was intersected. Jointing in the gneiss was prevalent with joint angles at 20 degree to the core axis. The gneiss is very oxidized and friable.

4.0: INTERVALS OF ECONOMIC INTEREST IN THE ONAKAWANA B DRILLHOLE

4.1: Oil and Gas:

Many structural and stratigraphic features, such as fault-bounded blocks, salt dissolution structures and biohermal facies, present in the Hudson Platform are similar to structures found in the southern Ontario portion of the Michigan Basin which contain oil and gas. Lower and Middle Devonian rocks (the Moose River, Murray Island, and Williams Island Formations) in the Moose River Basin have lithologically similar counterparts in the Michigan Basin which have produced substantial amounts of oil. Some trapping configurations in the Moose River Basin that have potential have been tested by exploratory drilling, but so far have not yielded commercial quantities of oil and gas. In the Onakawana B Drillhole, some very porous sections of rock occur in the upper carbonate member of the Williams Island Formation (between the 497.5' to 686.3' - 151.6m to 209.2m interval), but oil staining was not detected. The porosity in this member appears to be very variable and permeability may be good in some zones due to brecciation.

4.2: Gypsum:

Gypsum is known to occur in the Moose River Formation, especially in the southeastern portion of the Moose River Basin. The best exposures occur on the Moose River below Moose River Crossing and on the Cheepash River. Other exposures in this

formation occur at Gypsum Mountain, a slightly elevated area between the French and Abitibi Rivers. In the Onakawana B Drillhole, only short intersections of impure gypsum were intersected in the Moose River and Williams Island Formations (between drill intervals 657' to 674.5' - 200.3m to 205.6m and 936.5' to 993' - 285.4m to 302.7m, respectively). Individual bed thicknesses varied from 0.6 to 2.0 metres and consisted of cream-grey, coarse-crystalline, satin spar gypsum and impure, white-brown gypsum interspersed with dolostone.

4.3: Lignite:

The Onakawana lignite field, where the Onakawana A and B Drillholes were drilled, has been an area of considerable economic interest since the late 1920s. For years traders and native people in the area have known of the existence of lignite along the west bank of the Abitibi River close to Blacksmith Rapids. The Blacksmith Rapids are approximately 100 kilometres south of Moosonee and about 5 kilometres east of the Onakawana B Drillhole site.

In the summer of 1929, exploratory drilling in the area was carried out for the first time by the Ontario Department of Mines. The results indicated a substantial body of lignite and the Ontario Research Foundation was requested by the Department to undertake a technical and economic study of the deposit (see Dyer and Crozier 1933). Subsequently, a large tract of land

surrounding the area was withdrawn from staking by the Government.

Historically, the lignite in the deposit had been considered to occur as two parallel seams separated by a clay-sand interbed. The upper seam averages 7.5 metres in thickness and the lower seam averages 6 metres in thickness. When the Onakawana B hole was drilled, an additional 1.5 metres thick seam was discovered, 3 metres below the lowermost main seam (see Figure 6). This seam had not been reported in the Onakawana A Drillhole, and further work is needed to delineate the areal extent of the seam in the Onakawana lignite field. If it is extensive, it would add a significant amount to the total reserve calculations done for the Onakawana lignite field (presently estimated at 190 million tons (Trusler 1974)).

4.4: Oil Shale:

The Long Rapids Formation (a black fissile shale) is the only unit in the Moose River Basin that produces a petroliferous odour when freshly broken. This formation is correlative to other black shale units on the North American continent including the Kettle Point Formation (southwestern Ontario), the Antrim Shale (Michigan), the Ohio Shale (Allegheny Trough), the New Albany Shale (Illinois) and the Chattanooga Shale (Tennessee) (Bezys *et al.*, in preparation). The Long Rapids Formation has a good potential of being a source rock for conventional oil eventually

trapped in other units, but an even better potential as a shale oil resource.

Prompted by high energy costs, recent interest has focused on the stratigraphy and oil shale potential of the Long Rapids Formation. Total organic carbon content values from the Long Rapids Formation (between intervals 302.5' to 493.3' - 92.2m to 150.4m) in the Onakawana B Drillhole indicate values ranging between 0.42 to 5.69 % (Appendix E). Preliminary analyses from the Williams Island outcrop section of the Long Rapids Formation indicate some values greater than 10 %, which is roughly equivalent to a Fisher Assay oil yield of greater than 45 litres/tonne (Russell and Telford 1984). These oil yields could be doubled by using hydro retorting. More work is needed (using drillhole and outcrop information, and inorganic geochemical analyses) to delineate the thickest and richest black shale horizons and their areal extent.

5.0: CONCLUSIONS

The following conclusions may be drawn from examination of the core recovered from the Onakawana B Drillhole:

1. Surficial deposits account for the upper 22 metres of section, with approximately 16.5 metres represented by Quaternary units. The uppermost 5.5 metres were not recovered, but are thought to be organic material. The dominant lithology in the Quaternary is till with interglacial sediments. This is not a thick sequence of Quaternary sediments as compared to other localities in the basin.

2. Cretaceous age strata are represented by 55 metres of the Mattagami Formation, which consists of interbedded dark organic-rich claystones and lignite.

3. A new discovery in the Mattagami Formation is a 1.5 metres thick lignite seam not previously reported near the base of the Mattagami Formation, along with the re-identification of the other two previously defined seams in the Onakawana A Drill-hole. This new seam suggests more lignite may be present at Onakawana than previously thought.

4. The drilling of the Onakawana B Drillhole confirmed that the Long Rapids Formation is anomalously thick in the Onakawana area (approximately 80 metres in thickness).

5. The Middle Devonian carbonate strata could readily be subdivided into the Williams Island, Murray Island, and Moose River Formations (respectively 99.0, 16.0, and 48.0 metres in thickness).

6. The basal six metres of the Paleozoic strata had an unusual lithology of coarse-grained sandstone with scattered gypsum horizons.

7. Seven metres of highly weathered Precambrian granitic gneiss was encountered at the bottom of the hole.

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APPENDIX A

ONTARIO GEOLOGICAL SURVEY DRILL LOG
Onakawana B Drillhole
(50°35'24"N, 81°29'10"W)
(logged by J.Sanderson in 1985)

Depth ft(m)	Recovery (%)	Unit Description
0-18 (0-5.5)	0	No recovery (organic deposits).
18-22 (5.5-6.7)	25	**Marine and/or glaciolacustrine Unit**: grey to dark grey; clayey silt; grades downward into a silty, very fine-grained sand; lower 1.2 " (3cm) contains occasional very small fragments of broken shells; occasional small pebbles near the base; ?gradational to underlying unit. (Units transitional between Lake Barlow-Ojibway and Tyrell Sea sediments).
22-23 (6.7-7.0)	30	**Till (Cochrane?)**: sandy silt matrix; moderately compact; appears massive; approximately 5% clasts; majority of which are carbonate; poor recovery; base is transitional.
23-30 (7.0-9.1)	85	**Glaciolacustrine Unit (Friday Creek sediments?)**: grey-brown; silty clay; upper 4" (10cm) is laminated; (more massive below); occasional grits in upper 11.8" (30cm); no pebbles; thin (?Mg) coatings on fracture surfaces.
30-59 (9.1-18.0)	30	**Till (Adam or Matheson)**: grey; silt-rich matrix: dense; grey; calcareous; clast content 5-10%, mainly grits and pebbles; clasts are angular, some are striated; some slickenside surfaces on fractures in the till. **Granitic cobble or boulder** located 3.7m from the top of the till unit.
42-52 (12.8-15.8)	90	**Massive Till**: 5% clasts; clasts 95% carbonate lithologies.

52-59 (15.8-18.0)	100	**Till**: Increasing clast content with depth; lower 6" (15cm) of unit has poorly developed layering - possibly slump features; the interval 57-57.5'(17.4-17.6m) consists of a band of black till as found from (20-21m).
59-62 (18-18.9)	100	**Lacustrine Unit**: clay with silt partings, appears ?varved; laminae are contorted; dense; blocky.
62-65 (18.9-19.8)	0	No recovery
65-72 (19.8-21.9)	100	**Till**: black, silty clay till; moderately compact; clast content 5% (mostly grits and pebbles), 90% of the clasts are carbonate; unit is massive; slightly calcareous; woody fragments recovered at 67' (20.4m).

Mattagami Formation (Cretaceous):

72-97 (21.9-29.6)	100	**Claystone**: black; dense; blocky; "greasy" look and feel; apparent slickensides on fractures; massive; high organic content at 76' (3" coarse-grained sand bed).
97-102 (29.6-31.1)	0	No recovery
102-107 (31.1-32.6)	100	**Claystone**: black; slightly silty; dense; plastic; organic remains present; high water content.
107-112 (32.6-34.1)	0	No recovery
112-124 (34.1-37.8)	100	**Claystone**: grey to black; organic; dense; plastic; slickensides present.
124-150 (37.8-45.7)	100	**Lignite**: interbedded dark brown and red-brown lignite; red-brown lignite is of slightly higher density and fibrous when broken; marcasite (and pyrite) nodules disseminated sporadically throughout; some zones are very friable and unconsolidated.

150-152 (45.7-46.3)	100	**Claystone**: dark brown to grey; silty; plastic; dense; with minor dark grey lignite laminae.
152-156.5 (46.3-47.7)	100	**Lignite**: same as above.
156.5-164 (47.7-50)	0	No recovery; chip samples are dark black-grey, carbonaceous with lignite fragments.
164-165.5 (50-50.4)	100	**Interbedded sandy claystone and lignite**: dark grey organic clay with quartz sand interbedded with lignite; disseminated pyrite nodules associated with sandy layers.
165.5-167 (50.4-50.9)	100	**Quartz sand**: 164-167' (50-50.9m).
167-172 (50.9-52.4)	0	No recovery
172-177.5 (52.4-54.1)	100	**Claystone**: dark grey; silty; organic; dense; interbedded with dark black organic clay (reworked lignite?).
177.5-200 (54.1-61)	100	**Lignite**: dark brown; organic appearance; less dense; alternating with thinner interbeds of red-brown, more competent (woody) lignite; marcasite (and pyrite) blebs randomly oriented throughout; yellow, opaque spotting on core (non-metallic).
200-202 (61-61.6)	100	**Interbedded lignite and claystone**: very thin lignite seams interbedded with dark grey organic clay.
202-208 (61.6-63.4)	100	**Claystone**: dark brown; silty; plastic; dense clay with detrital lignite chips and fragments randomly oriented throughout; slickenside compactional features present.
208-210 (63.4-64)	100	**Interbedded lignite and claystone**: dark grey, dense, plastic, organic clay interbedded with lignite; completely lignite by 210' (64m).
210-215 (64-65.5)	100	**Lignite**: dark black and red-brown lignite (same as above).

215-238.5 (65.5-72.7)	61	**Claystone**: dark grey to brown-grey; silty; plastic; dense; carbonaceous interbeds and lignite chips; clay becomes grey below cross-cutting compactional feature at 223.5' (68.1m); core becomes more broken with depth, with fewer detrital lignite chips; scattered fragments of dark black shale are also present (probably Long Rapids Formation).
238.5-245 (72.7-74.7)	100	**Claystone**: light grey; dense with dark grey interbeds; clay is wavy laminated.
245-252 (74.7-76.8)	100	**Claystone**: grey to brown; massive; not as dense as before; lignite chips throughout; bottom contact is marked by lignite chips; alternating light and dark grey laminations (varve-like).

Long Rapids Formation (Upper Devonian):

252-277 (76.8-84.4)	100	**Interbedded green mudstone and shale with brown-black shale**: green mudstone and shales are silty; massive; non-fissile; some soft sediment deformation; scattered black laminae throughout; brown-black shales are slightly silty; thin bedded; non-calcareous; top and bottom contacts are both sharp and gradational. **Conodont Sample:** COB-1: 255'6"-256' (77.9-78m) COB-12: 252'-252'9" (76.8-77m) COB-13: 274'3"-275' (83.6-83.8m)
277-324.5 (84.4-98.8)	96	**Interbedded green mudstone and shale and brown-black shale**: green mudstone and shale (same as above) except slightly calcareous; shale content increasing; black shale laminae occur throughout; brown-black shales are slightly siltier; fissile; burrows at 311.6'(95m); black shale beds are increasing in proportion to green beds.

Conodont Samples:
COB-14: 281'5"-282'1" (85.8-86m)
COB-15: 289'3"-290' (88.2-88.4)
COB-16: 306'3"-307' (93.3-93.6m)
COB-17: 316'5"-317'1" (96.4-96.7m)
COB-18: 321'5"-322'1" (98-98.2m)
Hydrocarbon Sample:
OX-82: 92.2m

324.5-421.75 (98.8-128.5) 100

Interbedded brown-black shale and green mudstone and shale:
Brown-black shale: slightly silty; laminated to massive; non-calcareous; strong bituminous odour at 419' (127.7m); Lingula shells along some shale partings; bioturbated bases; increasing fissility with calcite concretions by 419' (127.7m).
Green shale and mudstone: variable interbedding of shales and mudstones; fissile; calcareous; bioturbated bases; concretionary bed and calcitic growth features at 416.5' (126.9m); bedding laminations becoming increasingly more apparent than before; high angle joints (45 degrees to core axis) at 399' (121.6m) and 409.5' (124.8m).
Conodont Samples:
COB-2: 360'4"-360'10" (109.8-110m)
COB-3: 399'-399'8" (121.6-121.8m)
COB-4: 402'1"-402'10" (122.6-122.8m)
COB-5: 405'7"-406'3" (123.5-123.8m)
COB-19: 333'1"-333'9" (101.5-101.7m)
COB-20: 347'-347'2" (105.7-105.8m)
and 347'8"-348'3" (106-106.1m)
COB-21: 367'6"-368' (112-112.2m)
COB-22: 379'-379'6" (115.5-115.7m)
COB-23: 389'-389'6" (118.6-118.7m)
COB-24: 395'-395'6" (120.4-120.5m)
COB-25: 410'-410'6" (125-125.1m)
COB-26: 415'-415'6" (126.5-126.6m)
COB-27: 419'4"-419'10" (127.8-128)
Hydrocarbon Samples:

OX-68: 127.7m	OX-75: 114.8m
OX-69: 126.7m	OX-76: 112.8m
OX-70: 124.9m	OX-77: 107.6m
OX-71: 125.4m	OX-78: 105.5m
OX-72: 122.7m	OX-79: 102.9m
OX-73: 119.8m	OX-80: 102.8m
OX-74: 118.7m	OX-81: 101.4m

421.75-440.5 (128.5-134.3)	100	**Shale**: green; massive with scattered calcareous concretions (both nodules and layers); some scattered pyritization; burrowed base. **Conodont Samples:** COB-6: 424'10"-425'8" (129.5-129.7m) COB-7: 438'6"-439'1" (133.7-133.8m) **Hydrocarbon Sample:** OX-67: 128.8m
440.5-444.5 (134.3-135.5)	100	**Shale**: black; massive; fissile; non-calcareous; burrowed towards the base; top contact gradational to sharp; strong bituminous odour.
444.5-454 (135.5-138.4)	100	**Mudstone**: green; massive; scattered calcite nodules; occasional burrows; grades into an interbedded green and grey mudstone; laminated; fissile in places; scattered pyrite nodules. **Conodont Sample:** COB-8: 447'-447'5" (136.2-136.4m) **Hydrocarbon Sample:** OX-66: 135.6m
454-457 (138.4-139.3)	100	**Shale**: brown-black; laminated; fissile; gradational base.
457-483.5 (139.3-147.4)	100	**Mudstone and shale**: green; random alternating massive, slightly calcareous mudstone and fissile shales with scattered calcareous concretions and nodules throughout; burrowed; thin black shale interbed at 465' (141.7m) with sharp base and top contacts. **Conodont Sample:** COB-9: 474'6"-475'4" (144.7-144.9m) **Hydrocarbon Sample:** OX-65: 139.5m

483.5-497.5 (147.4-151.6)	100	**Shale:** black; scattered silty laminae; massive; strong bituminous odour when broken; disseminated pyrite; silty band at 484' (147.5m); thin green mudstone interbed at 487' (148.4m); burrows throughout; scattered calcareous concretions; sharp erosional base. **Conodont Sample:** COB-30: 490'3"-490'9" (149.4-149.6m) **Hydrocarbon Sample:** OX-64: 150.4m

Williams Island Formation (Middle Devonian):
(Upper Carbonate Member)

497.5-511 (151.6-155.8)	98	**Mudstone:** light green grey; massive; calcareous; fossil hash at top contact - mainly Lingula fragments, with abundant brachiopods; water escape structures produce a brecciated appearance. **Conodont Samples:** COB-10: 497'8"-498'8" (151.7-152m) COB-31: 510'-510'6" (155.4-155.6m) **Hydrocarbon Sample:** OX-63: 153.2m
511-512.5 (155.8-156.2)	100	**Shale:** brown; calcareous silty laminations present; high angle joint (45 degrees to core axis) occurs at 511.25'(155.8m).
512.5-521.5 (156.2-158.9)	100	**Mudstone:** light green-grey; calcareous; occasional pyrite blebs; rare brachiopods. **Conodont Sample:** COB-32: 515'6"-516' (157.1-157.3m)
521.5-523.5 (158.9-159.6)	100	**Mudstone:** green-grey; calcareous; interbedded with brown mudstone/shale, similar to brown shale at 511-512.5'; dark colour resulting from Lingula fragments; disseminated pyrite crystals and blebs throughout.

523.5-530 (159.6-161.5)	100	**Shale/mudstone:** green; calcareous; shale beds interbedded with green mudstone; joint 60 degrees to core axis at 527' (160.6m); occasional limestone fragment interbedded with mudstone; lower 2' (60cm) appears more weathered and/or reworked. **Conodont Samples:** COB-11: 525'-526' (160-160.3) COB-33: 528'8"-529' (161.1-161.2)
530-549.5 (161.5-167.5)	79	**Brecciated interbedded limestone and mudstone:** limestone is light brown; fine to medium crystalline; sucrosic; poorly cemented; porous and vuggy; disseminated pyrite along brecciated faces; mudstone is dark grey, calcareous, non-fissile and infills the interstices; unit is heavily brecciated. **Conodont Sample:** COB-34: 548'6"-549' (167.2-167.3m)
549.5-551.5 (167.5-168.1)	100	**Limestone:** tan; medium crystalline; laminated; very porous; alternating with light brown subcrystalline (lithographic) limestone in pseudo-inclined bedding.
551.5-557.5 (168.1-169.9)	100	**Mudstone:** grey; calcareous; occasional pyrite blebs and limestone cobbles. **Conodont Sample:** COB-35: 555'-555'6" (169.2-169.3m)
557.5-562 (169.9-171.3)	100	**Mudstone and brecciated limestone:** grey; calcareous mudstone with brown sucrosic, fine-crystalline, laminated to thick-bedded brecciated limestone.
562-564 (171.3-171.9)	100	**Claystone:** dark grey-green; very plastic; calcareous; high water content; strong sulfur odour.
564-577.5 (171.9-176)	10	**Limestone:** tan; fine crystalline; sucrosic; irregularly bedded; scattered bituminous laminae; highly porous; some low porosity limestone with thin bedded, grey, calcareous mudstone interbeds. **Conodont Sample:** COB-36: 571'-571'6" (174-174.2m)

577.5-599 (176-182.6)	100	**Interbedded limestone and mudstone:** limestone: tan to brown; variably low and high porosity; fine crystalline; interbedded with dark grey calcareous mudstone; scattered bituminous laminae; somewhat fissile; thin bedded; one joint with some slickensides at 589' (179.5m); quartz grains in mudstone at 599' (182.6m).
599-610.5 (182.6-186.1)	100	**Limestone:** tan; very fine crystalline; calcarenaceous; with some fine-crystalline, highly porous saccharoidal limestone; minor clay/shale interbeds present; increasing clay/shale content by 610.5' (186.1m) with decreasing porosity.
610.5-613 (186.1-186.8)	100	**Mudstone:** dark grey; calcareous; with some mud clast rip-ups.
613-618 (186.8-188.4)	100	**Limestone:** orange to cream; fine crystalline; laminated; sucrosic; limonite staining along laminations.
618-628 (188.4-191.4)	100	**Mudstone:** green-grey; slightly silty; non-calcareous; massive with some angular limestone clasts; slickensides along some bedding planes; carbonaceous laminae along the bottom contact.
628-636.5 (191.4-194)	100	**Interbedded limestone and shale:** limestone: tan; fine crystalline; with fine-laminated, fissile, grey shale; some bituminous laminae.
636.5-639.5 (194-194.9)	100	**Limestone:** light brown; subcrystalline (lithographic); calcite veining and bituminous laminae present.
639.5-641.75 (194.9-195.6)	100	**Mudstone:** grey; non-calcareous; massive.

641.75-657 (195.6-200.3)	100	**Limestone**: brown to tan; fine to medium crystalline; nodular; highly porous with wispy black laminae; becomes less nodular and well bedded at 698' (212.8m) with first appearance of gypsum blebs.
657-660 (200.3-201.2)	100	**Gypsum**: white to dark brown; coarse crystalline.
660-662 (201.2-201.8)	100	**Mudstone**: grey; silty; calcareous; with interbedded satin spar gypsum lenses.
662-664.5 (201.8-202.3)	100	**Gypsum**: white to dark brown; coarse crystalline.
664.5-668 (202.3-203.6)	100	**Mudstone**: red; silty; plastic; random cross-cutting gypsum mineralization; sharp base.
668-674.5 (203.6-205.6)	100	**Gypsum**: white to brown; grading from coarse to fine crystalline by 674' (205.4m).
674.5-686.3 (205.6-209.2)	100	**Dolostone**: gypsiferous; tan; very fine crystalline; with interbeds of brown and white gypsum; sharp base.

Williams Island Formation (Lower Mudstone Member)

686.3-821.5 (209.2-250.4)	98	**Mudstone**: dark grey; slightly silty and calcareous; massive; random pyrite crystals throughout with an occasional disseminated pyrite lens and silty calcareous laminae; high angle shears at 763' and 779' (232.6-237.4m); interbedded with thin, dark grey, plastic clay; clay content increases towards the base; sharp base.

Murray Island Formation (Middle Devonian):

821.5-850.5 (250.4-259.2)	100	**Limestone**: light brown; calcisiltite; thin bedded; fossiliferous; with joints 40 degrees to core axis; occasional slickensides; thin, dark grey mud bed (8", 20cm thick) at 824'(251.2m); towards the base the limestone becomes more argillaceous, nodular, very fine to medium crystalline, with abundant brachiopods; vugs present, infilled with calcite.
850.5-858.5 (259.2-261.7)	100	**Limestone**: light brown; coarse crystalline; irregularly bedded; crinoidal; bioclastic; decreasing grain size by 858'(261.5m); becoming brecciated at 858.5'(261.7m).
858.5-873 (261.7-266.1)	97	**Brecciated limestone**: tan; fine to medium crystalline; thin bedded; porous; becoming poorly cemented with depth; some bituminous residue along brecciated fractures; small coral and brachiopod fossils at 867' and 869.5' (264.3-265m); lower contact sharp; consists of small limestone pebbles; no mud.

Moose River Formation (Middle Devonian):

873-879.5 (266.1-268.1)	100	**Brecciated limestone and mudstone**: limestone: grey brown; medium crystalline; irregularly bedded; limestone clasts occur to 874.5'(266.5m); mudstone: green-grey; contains angular limestone clasts of various sizes and compositions; becoming laminated by 879.5'(268.1m) with silty horizons.
879.5-880 (268.1-268.2)	100	**Limestone**: cream; coarse crystalline; laminated; very porous; calcarenaceous; ?could possibly be one large clast.

880-883 (268.2-269.1)	100	**Brecciated limestone and mudstone:** similar to brecciated zone above.
883-931.5 (269.1-283.9)	100	**Brecciated limestone:** light brown; medium crystalline matrix; irregularly bedded; containing large vugs; clasts are subcrystalline (lithographic), unfossiliferous, and very porous; by 893'(272.2m) consists of dark grey calcareous mudstone; variable limestone clast sizes.
931.5-936.5 (283.9-285.4)	10	**Mudstone:** light and dark grey at top; red at base; calcareous; mottled; thin carbonate bands with wavy bedding in red mudstones.
936.5-943 (285.4-287.4)	100	**Dolostone:** gypsiferous; very fine crystalline; with some light grey argillaceous dolostone beds; gypsum occurs as smokey blebs.
943-947 (287.4-288.6)	100	**Mudstone:** grey; massive; non-calcareous; contains satin spar gypsum lenses.
947-991 (288.6-302.1)	100	**Dolomitic limestone:** gypsiferous; light grey to brown; very fine crystalline; coarse crystalline smokey gypsum mineralization throughout; satin spar lenses occur at 990'(301.8m); scattered pinpoint porosity and wispy black laminae.
991-993 (302.1-302.7)	100	**Gypsum:** cream-grey; coarse crystalline; satin spar lenses.
993-1009 (302.7-307.5)	100	**Dolomitic limestone:** tan to grey green; argillaceous; very fine to fine crystalline; thin bedded; disseminated pyrite crystals and wispy black laminae randomly oriented throughout; first appearance of rose gypsum blebs at 996'(303.6m); becoming more arenaceous by 1009'(307.5m).

1009-1027.5 (307.5-313.2)	100	**Feldspathic sandstone**: very fine to coarse grained; arkosic with coarse-grained smokey gypsum nodules; calcareous; occasional interbed of grey-green shale laminae; sandstone becomes very poorly sorted by 1021'(311.2m) with rounded grains in a red mudstone matrix; ferric pigment staining to 1027.5'(313.2m).
1027.5-1029.5 (313.2-313.8)	100	**Sandstone**: cream; unsorted, fine to coarse grained; feldspathic; low ferruginous content.

Precambrian:

1029.5-1053 (313.8-320.9)	100	**Granite gneiss**: red; very weathered; jointing at 20 degrees to core axis; entire length is highly oxidized and very friable.

End of Hole.

APPENDIX B
DRILL LOG OF ONAKAWANA A DRILLHOLE
(logged by W.S.Dyer and W.Gerrie, January 1931 published in Martison 1953)

Depth ft(m)	Recovery (%)	Unit Description
0-6 (0-1.8)	0	Muskeg.
6-22 (1.8-6.7)	0	Soft, blue-grey marine clay.
22-60 (6.7-18.3)	0	Grey, boulder clay.
60-70 (18.3-21.3)	0	Black, plastic clay with an odd pebble (re-worked Cretaceous clay).
70-80 (21.3-24.4)	0	Black re-worked Cretaceous clay, sand, and gravel.
Cretaceous Sediments:		
80-82 (24.4-25)	0	Dark Cretaceous clay.
82-82.25 (25-25.1)	0	Lignite.
82.25-120 (25.1-36.6)	0	Dark-grey Cretaceous clay; at 120' (36.6m), coring begins.
120-123 (36.6-37.5)	0	Dark-grey Cretaceous clay;possibly a little sand.
123-146 (37.5-44.5)	40	Lignite.
146-147.5 (44.5-45)	0	Grey to black Cretaceous clay and fragments of lignite.
147.5-151 (45-46)	0	Lignite.
151-168 (46-51.2)	100	Dark grey Cretaceous clay.

168-173 (51.2-52.7)	0	White quartz sand.
173-194.5 (52.7-59.3)	0	Lignite.
194.5-199 (59.3-60.7)	0	Grey clay.
199-205 (60.7-62.5)	90	15" (38.1cm): Grey clay. 12" (30.5cm): Grey clay with lignite. 21" (53.3cm): Black clay. 15" (38.1cm): Grey clay with lignite fragments.
205-206.5 (62.5-62.9)	0	Lignite with a little clay.
206.5-210 (62.9-64)	100	12" (30.5cm): Lignitic clay. 13" (33cm): Lignite. 22" (55.9cm): Lignitic clay.
210-215 (64-65.6)	20	6" (15.2cm): Dark-grey clay with a little lignite. 6" (15.2cm): Cream-coloured clay.
215-224 (65.6-68.3)	40	6" (15.2cm): Mottled clay, grey and cream. 15" (38.1cm): Cream clay. 12" (30.5cm): Cream clay with lignite fragments. 0.5" (1.3cm): Lignite. 7" (17.8cm): Cream clay with lignite fragments.
224-236 (68.3-71.9)	30	19" (48.3cm): Cream-coloured clay with fragments of lignite. 21" (53.3cm): Banded grey and cream clay.
236-240 (71.9-73.2)	0	Bedded cream and grey clay with cream predominating; beds from 0.5-3 mm.
240-250 (73.2-76.2)	40	1" (2.5cm): Banded cream and grey clay. 41" (104.1cm): Cream clay with a few fragments of lignite.

		6" (15.2cm): Light greenish-grey clay.
Long Rapids Formation (Upper Devonian):		
250-262 (76.2-79.9)	40	3" (7.6cm): Greenish-grey clay with three thin bands of shale. 4" (10.2cm): Greenish-grey clay. 1" (2.5cm): Grey shale. 6" (15.2cm): Dark-cream clay, harder and older looking than the clay above 249' (75.9m). 2" (5.1cm): Soft, grey shale. 11" (27.9cm): Dark-green clay as above. 6" (15.2cm): Hard Cretaceous clay, dark cream. 4" (10.2cm): Grey banded shale. 21" (53.3cm): Light-greenish-grey clay 1" (2.5cm): Grey shale.
262-273 (79.9-83.2)	40	2" (5.1cm): Light greenish-grey clay. 1" (2.5cm): Grey shale. 6" (15.2cm): Light greenish-grey clay; all this clay seems older and more brittle than grey and cream clays above 249' (75.9m); preliminary tests with acid also suggest it contains more lime. 1" (2.5cm): Shale. 44" (111.8cm): Light greenish-grey clay with 0.5" (1.3cm) of shale at 30" (76.2cm).

273-283 (83.2-86.3)	50	17" (43.2cm): Hard, light-greenish-grey clay. 0.5" (1.3cm): Dark-grey shale. 2" (5.1cm): Clay. 0.5" (1.3cm): Shale. 0.5" (1.3cm): Clay. 1.5" (3.8cm): Shale. 2" (5.1cm): Clay. 1" (2.5cm): Shale. 4" (10.2cm): Clay. 1" (2.5cm): Shale. 3" (7.6cm): Clay. 2" (5.1cm): Shale. 6" (15.2cm): Clay. 1.5" (3.8cm): Shale. 2" (5.1cm): Clay. 0.5" (1.3cm): Shale. 3" (17.8cm): Clay. 1" (2.5cm): Shale. 1" (2.5cm): Clay. 4" (10.2cm): Shale.
283-293 (86.3-89.3)	60	5" (12.7cm): Clay. 1" (2.5cm): Shale. 2" (5.1cm): Clay. 6" (15.2cm): Shale. 3" (7.6cm): Clay. 3" (7.6cm): Shale. 1" (2.5cm): Clay. 8" (20.3cm): Shale. 2" (5.1cm): Clay. 7" (17.8cm): Shale. 8" (20.3cm): Clay. 3" (7.6cm): Shale. 8" (20.3cm): Clay. 0.5" (1.3cm): Shale. 4" (10.2cm): Clay. 3" (7.6cm): Shale. 3" (7.6cm): Clay. 1" (2.5cm): Shale. Clay 249' (75.9m) down, all the same, chalky pale greenish-grey clay.

293-304 (89.3-92.7)	65	3" (7.6cm): Clay. 9" (22.9cm): Shale. 9" (22.9cm): Clay. 1" (2.5cm): Shale. 6" (15.2cm): Clay. 8" (20.3cm): Shale. 5" (12.7cm): Clay. 10" (25.4cm): Shale. 7" (17.8cm): Clay. 13" (33cm): Shale. 2" (5.1cm): Clay. 9" (22.9cm): Clay.
304-314 (92.7-95.7)	75	18" (45.7cm): Clay. 1" (2.5cm): Shale. 6.5" (16.5cm): Clay. 1.5" (3.8cm): Shale. 2" (5.1cm): Clay. 3.5" (8.9cm): Shale. 3" (7.6cm): Clay. 1" (2.5cm): Shale. 8" (20.3cm): Clay. 5" (12.7cm): Shale. 2" (5.1cm): Clay. 4" (10.2cm): Shale. 18" (45.7cm): Clay. 3" (7.6cm): Shale. 9" (22.9cm): Clay. Clays the same.
314-324 (95.7-98.7)	100	12" (30.5cm): Clay. 1" (2.5cm): Shale. 1" (2.5cm): Clay. 4" (10.2cm): Shale. 13" (33cm): Clay. 6" (15.2cm): Shale. 12" (30.5cm): Clay. 6" (15.2cm): Shale. 5" (12.7cm): Clay. 10" (25.4cm): Shale. 4" (10.2cm): Clay. 19" (48.3cm): Shale. 1" (2.5cm): Clay. 27" (68.6cm): Shale. 1" (2.5cm): Clay. 9" (22.9cm): Shale.

324-335 (98.7-102.1)	50	38" (96.5cm): Shale. 5" (12.7cm): Clay. 1" (2.5cm): Shale. 1.5" (3.8cm): Interbanded clay and shale. 12" (30.5cm): Shale. 1" (2.5cm): Clay. 1" (2.5cm): Shale.
335-346 (102.1-105.5)	95	8" (20.3cm): Shale. 1" (2.5cm): Clay. 42" (106.7cm): Shale. 1" (2.5cm): Clay. 40" (101.6cm): Shale. 10" (25.4cm): Clay. 6" (15.2cm): Shale. 1.5" (3.8cm): Banded shale and clay. 4" (10.2cm): Clay. 4" (10.2cm): Shale. 3" (7.6cm): Clay. Clays the same.
346-356 (105.5-108.5)	100	12" (30.5cm): Shale. 6" (15.2cm): Clay. 10" (25.4cm): Shale. 1" (2.5cm): Clay. 18" (45.7cm): Shale. 1" (2.5cm): Banded shale and clay. 5" (12.7cm): Shale. 1" (2.5cm): Banded clay and shale. 20" (50.8cm): Shale. 7" (17.8cm): Clay. 7" (17.8cm): Shale. 1" (2.5cm): Banded clay and shale. 3" (7.6cm): Clay. 5" (12.7cm): Shale. 1.5" (3.8cm): Banded clay and shale. 13" (33cm): Shale. 1" (2.5cm): Clay. 5" (12.7cm): Shale. 6.5" (16.5cm): Clay. 0.5" (1.3cm): Shale. 1" (2.5cm): Clay.
356-358 (108.5-109.1)	10	2.5" (6.4cm): Shale. 0.5" (1.3cm): Clay.

358-368 (109.1-112.2)	100	4" (10.2cm): Concretion, ankerite (?). 2" (5.1cm): Clay. 21" (53.3cm): Shale. 4" (10.2cm): Clay. 3.5" (8.9cm): Shale. 2" (5.1cm): Clay. 27" (68.6cm): Shale. 1" (2.5cm): Banded shale and clay. 18" (45.7cm): Shale. 6" (15.2cm): Clay. 16" (40.6cm): Shale. 1" (2.5cm): Clay. 6" (15.2cm): Shale. 6" (15.2cm): Clay. 4" (10.2cm): Shale. 3" (7.6cm): Clay.
368-383 (112.2-116.7)	70	48" (121.9cm): Shale. 2" (5.1cm): Banded shale and clay. 3" (7.6cm): Shale. 1.5" (3.8cm): Clay. 1.5" (3.8cm): Shale. 4" (10.2cm): Clay. 1" (2.5cm): Shale. 3.5" (8.9cm): Clay. 7" (17.8cm): Shale. 2" (5.1cm): Clay. 6" (15.2cm): Shale. 3" (7.6cm): Clay. 5" (12.7cm): Shale. 6" (12.7cm): Clay. 19" (48.3cm): Shale. 2" (5.1cm): Clay. 5" (12.7cm): Shale. 2" (5.1cm): Clay. 1.5" (3.8cm): Shale. All shale has same dark-grey character.

383-393 (116.7-119.8)	100	59" (149.9cm): Shale. 1.5" (3.8cm): Clay. 2" (5.1cm): Shale. 3" (7.6cm): Clay. 4" (10.2cm): Shale. 1" (2.5cm): Clay. 29" (73.7cm): Shale. 1.5" (3.8cm): Clay. 4" (10.2cm): Shale. 3.5" (8.9cm): Banded clay and shale. 3" (7.6cm): Shale. 1.5" (3.8cm): Banded clay and shale (fossil). 9" (22.9cm): Shale.
393-404 (119.8-123.1)	95	60" (152.4cm): Shale. 2" (5.1cm): Banded, mostly clay. 63" (160cm): Shale.
404-414 (123.1-126.2)	100	30" (76.2cm): Shale [fossil fragment at 7" (17.8cm)]. 2.5" (6.4cm): Clay. 6" (15.2cm): Shale. 3.5" (8.9cm): Clay. 15" (38.1cm): Shale. 2" (5.1cm): Clay. 16" (40.6cm): Shale. 4" (10.2cm): Hard, greenish-grey clay with Lingula. 13" (33cm): Shale. 8" (20.3cm): Concretion (ankerite?), fractured, and fractures filled with crystalline calcite. 0.5" (1.3cm): Clay. 17" (43.2cm): Shale. Clay harder, like shale, but same pale-greenish-grey colour.

414-424 (126.2-129.2)	100	11" (27.9cm): Shale. 80" (203.4cm): Pale-green clay, hard, like shale. 17" (43.2cm): Crumbly, pale greenish-grey shaly clay. 1" (2.5cm): Hard, pale-green clay. 4" (10.2cm): Crumbly clay. 2" (5.1cm): Hard, pale shaly clay. 10" (25.4cm): Crumbly clay.
424-435 (129.2-132.6)	100	6" (15.2cm): Pale, crumbly shaly clay. 30" (76.2cm): Hard, pale shaly clay. 56" (142.2cm): Pale, crumbly clay. 39" (99.1cm): Hard, pale shaly clay.
435-445 (132.6-135.6)	50	11" (27.9cm): Dark-grey shale. 1" (2.5cm): Pale, hard, greenish-grey clay. 7" (17.8cm): Banded shale and clay. 11" (27.9cm): Dark-grey shale. 2" (5.1cm): Hard, green clay. 6" (15.2cm): Dark-grey shale. 1.5" (3.8cm): clay. 5.5" (14cm): Shale. 2" (5.1cm): Pale, grey-green, shaly clay with nodules of pyrite. 1" (2.5cm): Pale clay. 1.5" (3.8cm): Shaly clay with nodules of pyrite. 1" (2.5cm): Pale clay.
445-458 (135.6-139.6)	35	2.5" (6.4cm): Pale clay. 1" (2.5cm): Concretion. 4.5" (11.4cm): Pale clay. 3" (7.6cm): Concretion. 4" (10.2cm): Pale clay, greenish (brachiopods removed). 26" (66cm): Dark-grey shale. 6" (15.2cm): Pale clay. 6" (15.2cm): Banded shale and clay.

458-461 (139.6-140.5)	100	2" (5.1cm): Pale clay. 1" (2.5cm): Shale. 5" (12.7cm): Clay. 3" (7.6cm): Dark shale. 5" (12.7cm): Clay. 2" (5.1cm): Dark shale. 14" (35.6cm): Clay.
461-472 (140.5-143.9)	80	29" (73.7cm): Hard, pale, greenish-grey clay. 1" (2.5cm): Dark grey shale. 3.5" (8.9cm): Concretion, nodules of pyrite, veins of calcite. 9" (22.9cm): Pale, hard shaly clay. 8" (20.3cm): Crumbly pale greenish-grey; all clays, greenish-grey from 250' (76.2m) down. 10" (25.4cm): Hard, pale clay. 1" (2.5cm): Concretion. 5" (12.7cm): Pale, hard clay. 3" (7.6cm): Concretionary matter, veins of calcite. 21" (53.3cm): Pale, hard, shaly clay. 6" (15.2cm): Concretionary matter, veins of calcite. 6" (15.2cm): Pale, hard, shaly clay.
472-482 (143.9-146.9)	95	1" (2.5cm): Pale-greenish clay. 24" (61cm): Grey shaly clay (without greenish caste). 3" (7.6cm): Concretionary (veins of calcite). 19" (48.3cm): Grey shaly clay. 14" (35.6cm): Crumbly, grey shaly clay. 3" (7.6cm): Concretionary (veins of calcite). 27" (68.6cm): Grey, shaly clay. 4" (10.2cm): Concretionary. 20" (50.8cm): Dark-grey shale; small concretion at 8" (20.3cm).

482-488 (146.9-148.7)	85	18" (45.7cm): Dark, grey shale; seam of pyrite at 5" (12.7cm). 2" (5.1cm): Banded shale and pale clay. 30" (76.2cm): Dark-grey shale. 4" (10.2cm): Concretionary material. 5" (12.7cm): Dark-grey shale.
488-491 (148.7-149.7)	50	15" (38.1cm): Dark-grey shale.
491-499 (149.7-152.1)	60	2.5" (6.4cm): Dark-grey shale. 2" (5.1cm): Pale-greenish-grey clay. 25" (63.5cm): Dark-grey shale; last 12" (30.5cm) crumbly. 17" (43.2cm): Crumbly, grey shaly clay. 11" (27.9cm): Grey shaly clay with Lingula at 4" (10.2cm).
499-508 (152.1-154.8)	100	78" (198.1cm): Grey shale; fossiliferous from 499-505' (152.1-153.9m). 18" (45.7cm): Pale-greenish-grey clay; fairly hard. 9" (22.9cm): Dark-grey shale.
508-513 (154.8-156.4)	50	32" (81.3cm): Grey shaly clay. 1" (2.5cm): Concretion (?).
513-525 (156.4-160)	40	3" (7.6cm): Concretion. 18" (45.7cm): Grey shaly clay. 4" (10.2cm): Concretion. 3" (7.6cm): Grey shaly clay (brachiopods removed). 8" (20.3cm): Concretion. 0.5" (1.3cm): Grey shaly clay. 2" (5.1cm): Concretion. 5" (12.7cm): Grey shaly clay (brachiopods removed). 2" (5.1cm): Concretion. 7" (17.8cm): Grey shaly clay.

Williams Island Formation (Middle Devonian):

525-541 (160-164.9)	40	23" (58.4cm): Grey shaly clay. 1" (2.5cm): Concretion (?). 8" (20.3cm): Grey shaly clay. 1" (2.5cm): Concretion. 1" (2.5cm): Clay. 1.5" (3.8cm): Concretion. 14" (35.6cm): Crumbly, grey shaly clay. 11" (27.9cm): Porous and cavernous grey limestone. 15" (38.1cm): Banded grey limestone.
541-547 (164.9-166.7)	15	2" (5.1cm): Fine-grained porous cream limestone. 6.5" (16.5cm): Banded limestone cream-grey. 3" (7.6cm): Fine-grained, porous cream limestone.
547-555 (166.7-169.2)	50	5" (12.7cm): Porous and cavernous buff limestones showing brecciation. 18" (45.7cm): Grey shaly limestone, fractured and cemented. 6" (15.2cm): Brecciated shale-limestone, mostly shale. 6" (15.2cm): Clay shale. 2" (5.1cm): Brecciated shale-limestone, grey. 13" (33cm): Buff porous limestone, fine-grained.
555-565 (169.2-172.2)	15	1" (2.5cm): Buff cavernous limestone which represents 2' (0.6m) of limestone drilled. 15" (38.1cm): Brecciated material, clay and limestone fragments, which represent 8' (2.4m) of clay mixed with fragments of the above limestone.

565-571 (172.2-174)	30	13" (33cm): Brecciated clay and limestone representing 2' (0.6m) of drilling. 14" (35.6cm): Representing 18" (45.7cm) fine-grained buff, porous, probably cavernous limestone.
571-576 (174-175.6)	25	3" (7.6cm): Very porous, buff limestone. 10" (25.4cm): Less porous, buff limestone, probably cavernous (brachiopods removed).
576-583 (175.6-177.7)	30	4" (10.2cm): Brecciated clay and limestone representing 18" (45.7cm) of clay. 3.5" (8.9cm): Shale-limestone breccia, limestone predominating, natural breccia. 21" (53.3cm): Buff-grey, fine-grained slightly cavernous limestone.
583-600 (177.7-182.9)	40	42" (106.7cm): Grey, massive shaly limestone. 9" (22.9cm): Massive shaly limestone, grey, less argillaceous. 7" (17.8cm): Buff, fine-grained porous limestone. 20" (50.8cm): Thin-bedded, grey shale and buff limestone. 7" (17.8cm): Porous, banded buff limestone.
600-616 (182.9-187.8)	50	49" (124.5cm): Very porous, bedded buff limestone. 17" (43.2cm): Grey-shale-limestone breccia, fragments grey shale and buff limestone. 9" (22.9cm); Crumbly, grey shaly clay. 7" (17.8cm): Shale-limestone breccia as above. 17" (43.2cm): Banded, buff limestone, slightly porous.

616-626 (187.8-190.8)	100	3" (7.6cm): Dense, buff grey limestone. 11" (27.9cm): Buff-grey, limy shale. 10" (25.4cm): Buff calcareous shale, no bedding. 9" (22.9cm): Buff-grey calcareous shale. 81" (205.7cm): Hard, massive, buff calcareous shale. 3" (7.6cm): Buff limestone. 3.5" (8.9cm): Thin-bedded shaly limestone, possible fossil fragments.
626-632 (190.8-192.6)	50	4" (10.2cm): Clay containing limestone pebbles, possibly representing band of clay. 21" (53.3cm): Thinly bedded, dense, buff-grey limestone, lower 6" (15.2cm) brecciated. 9" (22.9cm): Fractured limestone, fractures filled with calcite, 1" (2.5cm) shows slickensides. 5" (12.7cm): Buff-grey calcareous shale.
632-637 (192.6-194.2)	75	3" (7.6cm): Buff-grey calcareous limestone. 6" (15.2cm): Buff, fine-grained limestone. 17" (43.2cm): Porous, banded, buff limestone. 12" (30.5cm): Fine-grained, buff-grey limestone. 3" (7.6cm): Grey calcareous shale.
637-647 (194.2-197.2)	25	24" (61cm): Crumbly, grey, calcareous shale. 5" (12.7cm): Porous, buff limestone.
647-655 (197.2-199.6)	60	52" (132.1cm): Buff, fine-grained granular limestone, not much bedding. 1" (2.5cm): White gypsum.

655-665 (199.6-202.7)	60	7" (17.8cm): Grey clay, possibly represents a cave. 27" (68.6cm): Pure gypsum. 15" (38.1cm): Grey calcareous shale carrying gypsum and selenite veins. 1" (2.5cm): Gypsum. 9" (22.9cm): Red shale carrying gypsum. 4" (10.2cm): Grey shale carrying gypsum. 11" (27.9cm): Red fragmentary, shaly material, probably shale carrying gypsum; green band at 9" (22.9cm).
665-675 (202.7-205.7)	75	7" (17.8cm): Reddish, fragmentary material, green band at 2" (2.5cm). 2" (2.5cm): Green shaly gypsum rock. 4" (10.2cm): Reddish gypsum. 46" (116.8cm): Pure grey gypsum. 31" (78.7cm): Gypsum bearing grey and buff shale, numerous veins of selenite.
675-677 (205.7-206.3)	90	12" (30.5cm): Thin-bedded calcareous shale, buff-grey. 8.5" (21.6cm): Gypsum bearing shale rock.
677-687 (206.3-209.4)	95	70" (177.8cm): Buff gypsum shale; numerous veins of selenite. 17.5" (44.5cm): Hard, buff-grey calcareous shale; spotted. 26" (66cm): Massive grey hard calcareous shale.
687-690 (209.4-210.3)	100	10" (25.4cm): Hard, grey calcareous shale. 28" (71.1cm): Grey shale, slightly calcareous.
690-701 (210.3-213.7)	100	121" (307.3cm): Massive, grey shale.

701-713 (213.7-217.3)	100	151" (383.5cm): Massive, grey shale.
713-726 (217.3-221.3)	100	156" (396.2cm): Grey shale.
726-737 (221.3-224.6)	100	124" (315cm): Grey shale.
737-748 (224.6-228)	100	141" (358.1cm): Grey shale.
748-760 (228-231.7)	90	123" (312.4cm): Grey shale.
760-774 (231.7-235.9)	100	173" (439.4cm): Grey shale.
774-786 (235.9-239.6)	60	86" (218.4cm): Grey shale.
786-796 (239.6-242.6)	100	120" (304.8cm): Grey shale.
796-806 (242.6-245.7)	0	Grey shale; at 806' (245.7m) casing divided in two places; poor recovery from 806' (245.7m) down; only fragments of core recovered; some of this core was burned in an accident to drill and drill stock.
806-825 (245.7-251.5)	15	42" (106.7cm): Grey shale. 1" (2.5cm): Buff limestone.
825-836 (251.5-254.8)	30	40" (101.6cm): Grey shale. 2" (5.1cm): Brown limestone.

Murray Island Formation (Middle Devonian):

836-848.5 (254.8-258.6)	40	60" (152.4cm): Buff limestone showing small vugs of calcite and a few fossils, mostly brachiopods, etc.

848.5-862 (258.6-262.7)	33	54" (137.2cm): Buff fossiliferous limestone, crinoid columns, brachiopods, etc.
862-873 (262.7-266.1)	20	24" (61cm): Buff limestone with few fossils.

Moose River Formation (Middle Devonian):

873-892 (266.1-271.9)	10	1.5" (3.8cm): Thinly bedded limestone and shale, no fossils; consisting of eight small pieces of dense cream limestone with no fossils. 6.5" (16.5cm): Soft, grey shaly material.
892-909 (271.9-277.1)	15	36" (91.4cm): Limestone breccia.
909-920 (277.1-280.4)	25	36" (91.4cm): Limestone breccia; core from 806-920' (245.7-280.4m) burned.
920-936 (280.4-285.3)	40	84" (213.4cm): Core recovered in small pieces, pale-buff limestone, porous and probably cavernous, also shale-limestone breccia.
936-946 (285.3-288.3)	40	52" (132.1cm): Grey gypsum-bearing shale with veins of selenite; gypsum predominates.
946-956 (288.3-291.4)	35	44" (111.8cm): Grey gypsum-bearing shale with veins of selenite; gypsum predominates.

956-968 (291.4-295.1)	90	20" (50.8cm): Hard, whitish-grey gypsum shale. 24" (61cm): Granular, impure limestone carrying gypsum. 55" (139.7cm): Buff gypsum bearing argillaceous shale. 12" (30.5cm): Fairly pure gypsum, most of it in the form of selenite. 16" (40.6cm): Buff gypsum-bearing argillaceous shale. 4" (10.2cm): Buff, granular limestone, dissolves slowly in acid, may be dolomitic.
968-980 (295.1-298.7)	65	2" (5.1cm): Buff granular limestone. 1.5" (3.8cm): Shale. 6" (15.2cm): Buff limestone or shale carrying selenite veins. 84" (213.4cm): Buff, rather massive granular limestone, may be dolomitic.
980-990 (298.7-301.8)	75	83" (210.8cm): Buff, massive granular arenaceous limestone with minute selenite crystals. 1" (2.5cm): Gypsum. 6" (15.2cm): Gypsum-bearing limestone, 25 % gypsum.
990-996 (301.8-303.6)	40	15" (38.1cm): Buff, massive granular arenaceous limestone, needles of selenite, odd vein of selenite. 4" (10.2cm): Green-grey gypsum shale. 7" (17.8cm): Arenaceous buff limestone. 8" (20.3cm): Fragments of greenish shale and gypsum.

996-1008 (303.6-307.2)	75	14" (35.6cm): Green, granular arenaceous limestone. 1" (2.5cm): Pure-white gypsum. 18" (45.7cm): Green, granular arenaceous limestone. 10" (25.4cm): Green, arenaceous limestone replaced to a great extent by pink selenite. 13" (33cm): Green and white calcareous sandstone with veins of selenite.
		10" (25.4cm): Greyish-green calcareous sandstone, 0.5" (1.3cm) bed of dark grit at 8" (20.3cm). 3.5" (8.9cm): Gypsum replacement rock. 33" (83.8cm): Green and grey calcareous sandstone, showing bedding. 2" (5.1cm): reddish sandstone. 2" (5.1cm): Grey calcareous sandstone. 0.5" (1.3cm): Reddish sandstone.
1008-1020 (307.2-310.9)	90	3" (7.6cm): Pink gypsum with a little sandstone. 6" (15.2cm): Bedded green sandstone with vein of gypsum. 5" (12.7cm): Coarse red sandstone with bedding. 7.5" (19.1cm): Coarser, bedded green sandstone with a little gypsum. 2" (5.1cm): Gypsum. 12" (30.5cm): Red and green sandstone, red predominant, with vein of gypsum. 10" (25.4cm): Green and reddish green sandstone. 3" (7.6cm): Gypsum sandstone. 4" (10.2cm): Red and green banded sandstone, coarse. 27" (68.6cm): Grey-green sandstone bedded with some thin, buff beds and a few selenite veins. 10" (25.4cm): Interbedded red-

		green sandstone and fine gritstone. 18" (45.7cm): Coarse, reddish quartzose gritstone, fragments of quartz and feldspar up to 0.5" (1.3cm). 3" (7.6cm): Fairly coarse, greenish-grey gritstone. 11" (27.9cm): Greenish-grey sandstone. 2" (5.1cm): Coarse, greenish-grey gritstone.
1020-1027 (310.9-313)	25	4" (10.2cm): Coarse, greenish-grey gritstone. 9" (22.9cm): Red sandstone and fine gritstone. 4" (10.2cm): Coarse, reddish gritstone. 2" (5.1cm): Reddish sandstone. 3" (7.6cm): Grey-green sandstone.
Precambrian:		
1027-1037 (313-316.1)	3	Broken core, very weathered, syenite gneiss, decomposed feldspar, and chlorite.
1037-1042 (316.1-317.6)	10	6" (15.2cm): Fine-grained weathered granite gneiss.
1042-1047 (317.6-319.1)	0	12" (30.5cm): Red sandy material looking like decomposed Precambrian rock.
1047-1057 (319.1-322.2)	0	No core.
1057-1060 (322.2-323.1)	50	19" (48.3cm): Weathered pink granite gneiss; feldspar predominates with the minerals chlorite and quartz.

End of Hole

APPENDIX C

TECHNICAL OPERATIONS OF THE ONAKAWANA B DRILLHOLE

The Ontario Geological Survey Onakawana B Drillhole was drilled by Longyear Canada Inc. under the planning and field management by the staff of Golder Associates. The hole took a total of 35 days to complete in February and March of 1985.

The local topography at the drill site reflects the general, flat-lying nature of the regional topography, with the area dominated by marshy terrain, stagnant lakes and meandering rivers. The climate of the area is variable with moderate conditions in the summer to severe conditions in the winter. Minimum daily temperatures during winter can reach -20°C to -30°C under normal conditions.

During the drilling of the Onakawana B Drillhole (February-March, 1985), temperatures were higher than normal, often hovering near the freezing point. However, some lows of -30°C were recorded (Figure 7). These temperature variations (to temperatures approaching freezing point) at the start of the project adversely affected the initial phase of site set-up and road preparation through the resulting wet and slushy conditions.

Helicopter Reconnaissance:

A helicopter reconnaissance was undertaken to identify the drill site and clarify logistical details (such as road and ice bridge preparation) in early February. Ranger Helicopters Ltd. of

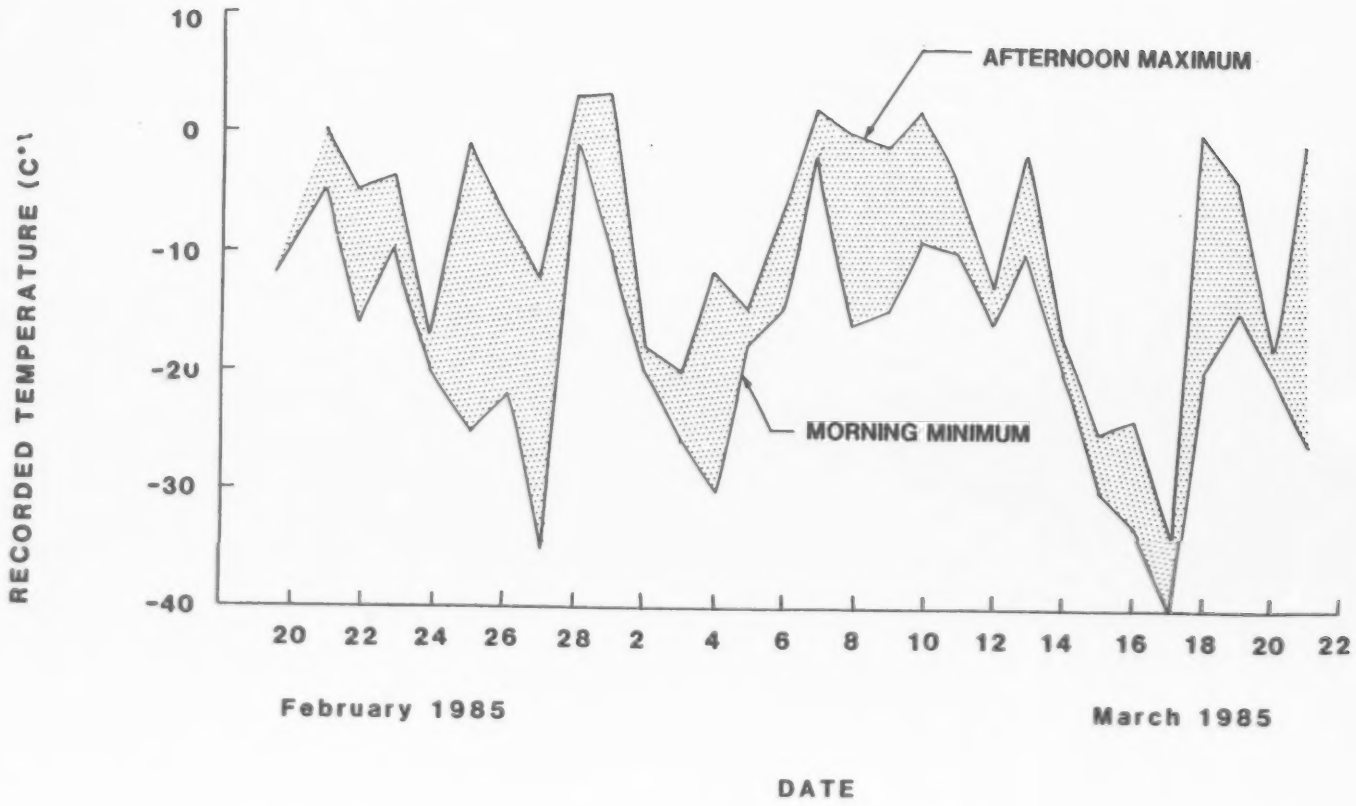

Figure 7: Daytime temperature ranges during the drilling of the Onakawana B Drillhole (readings were taken at the Onakawana camp site)

Cochrane, Ontario, was used to transport Golder, Longyear and OGS personnel from Timmins to the Onakawana B Drillhole site. During this initial visit, the proposed crossing site over the Onakawana River was checked for ice thickness, as were the condition of the river bank slopes. The ice was considered to be thick enough to support the machinery needed to drill the hole, and the river banks considered reliable for a skid mounted drill rig and associated equipment. The snow depth along the proposed road access to the drill site was approximately 0.5-0.6 m.

Site Mobilization:

On February 18th, 1985, an advance crew of Longyear personnel moved via the Ontario Northland Railway to the Onakawana site. The equipment consisted of a Longyear 38 drill and associated pumps, tanks, rods, casing, etc., a John Deere 450 tractor with winch, and a Log Skidder.

Work was started on the winter access road to the drill site from the Onakawana railway siding on February 19th with the John Deere tractor. Some difficulties were experienced because of thawing conditions and on February 21st the tractor broke through the frost layer at the proposed drill site location. It became obvious that a marginal level of frost was present in the ground below the snow to support the drill rig. Other alternative sites were checked by use of snowmobiles and snowshoes, but it was found that the condition of insufficient frost depth was widespread throughout the area. Accordingly, no better site was

found, and a decision was reached to drill at the originally selected drill site.

On the access road, a corduroy ice bridge was constructed over the Onakawana River, after it was discovered water had seeped up through holes in the ice to cause slushiness of the ice bridge. A corduroy crib set-up was arranged for the drill site and the logs needed were cut and hauled about 1.5 kilometres from the Onakawana River to the drill site.

Mobilization took a total of 9 days. This extended set-up time was largely a result of mechanical problems and difficulties with the access road.

Base Camp Set-up:

Under a subcontract to the Ontario Northland Railway, box-car accommodations were provided by the railway. The base camp was set-up on an inactive railway siding at Onakawana. The camp consisted of the following:

- 1 cook car which sleeps 3 people,
- 1 sleeping car which sleeps 4 people,
- 1 Atco trailer which sleeps 4 people,
- 1 shower car, and
- 2 generator cars.

A party line telephone was installed in the cook car by the telecommunications division of the ONR Railway.

DRILLING OF THE ONAKAWANA B DRILLHOLE

(Technical Aspects)

Recent, Quaternary and Mesozoic Units [PQ-3 (83.0 mm diameter) Drilling]:

On February 28th, 2:00 AM, drilling operations commenced on the Onakawana B Drillhole (Figure 8). PW casing was drilled to approximately 13' (4m) through the peat, and a mud return line was set-up. The hole was then drilled to 72' (21.9m) using PQ-3 equipment with PW casing following the drill progress. The casing was set to a depth of 33' (10.1m).

The hole was continued uncased with PQ-3 rods from 73 to 102' (21.9-31.1m) in two shifts. Considerable quantities of drilling mud were used in this interval. At 102' (31.1m), all mud returns were lost as the hole was squeezing below the PQ drill rods. Consequently, drilling was stopped on March 2nd.

An additional 100' (30.5m) of PW casing arrived at the drill site on March 4th, and it was then possible to advance the PW casing to 102' (31.1m). Drilling then recommenced with PQ-3 to 112' (34.1m). The hole was again found to be squeezing below the PQ drill rods and all circulation returns were lost. It was determined necessary to ream the casing to the bottom of the hole, however, at this point it was found that the drill could not turn the casing so it had to be hammered back with a 350lb (158.8kg) casing hammer before it could be freed. After hammering and pumping mud down the casing for most of a shift, it was possible to advance the 102' (31.1m) of PW casing.

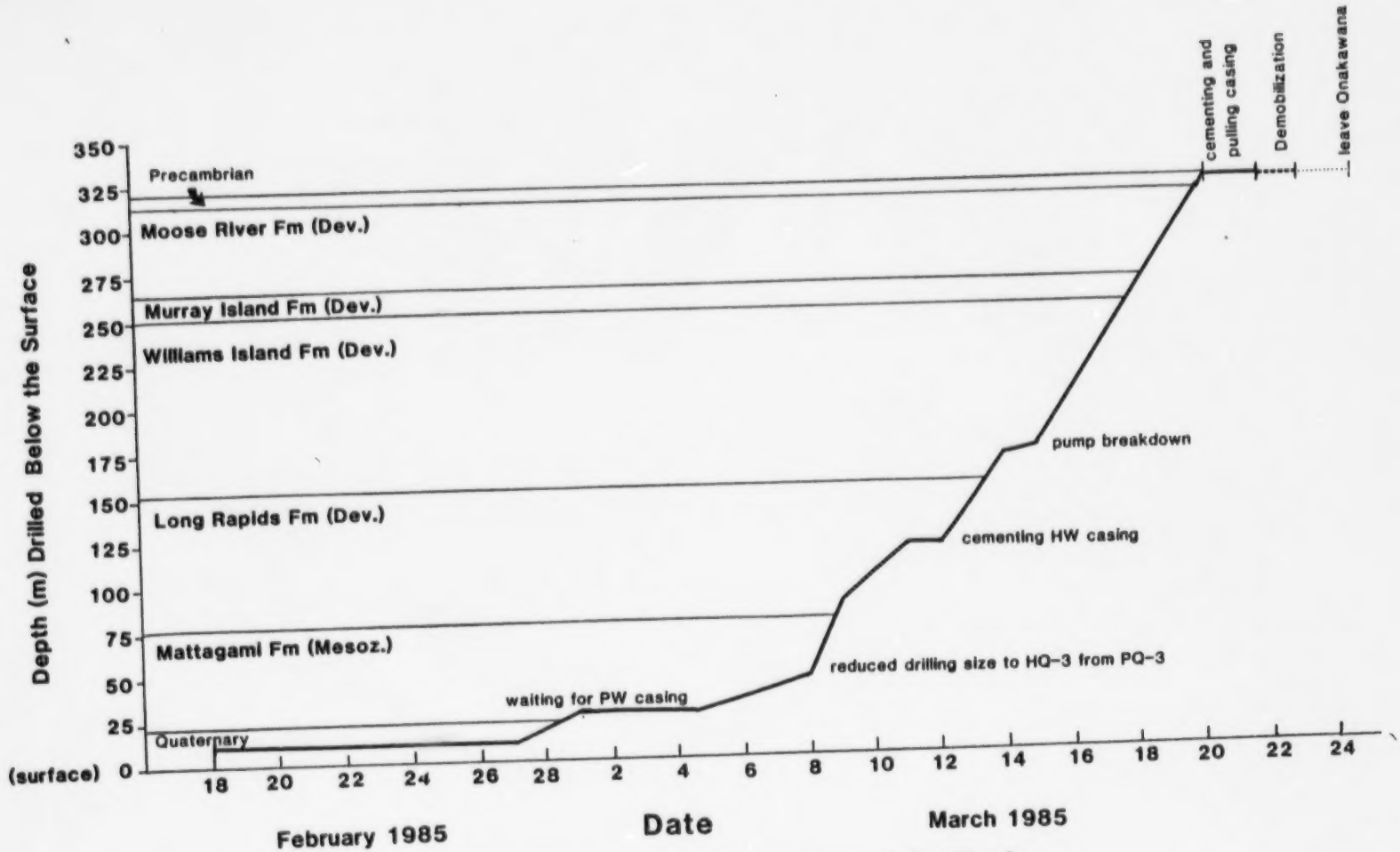

Figure 8: Drilling progress of the Onakawana B Drillhole

Further drilling to 120' (36.6m) was carried out with the PW casing which followed immediately behind the core barrel. The hole was then cored ahead of the casing to a depth of 162' (49.4m) and again, circulation was lost and the hole caved back to approximately 160' (48.8m). A reduction from PQ to HQ (61.1mm diameter) coring was carried out at this time.

In order to reduce to HQ, several modifications were required to the existing set-up. Some difficulty was encountered in making these changes, the most important being those arising from attempting to remove the chuck rod and the adapter plug from the top of the PW casing. In order to break the machine tightened joint on these components, it was necessary to winch with a 48" (121.9cm) pipe wrench set on the casing adapter.

Quaternary and Mesozoic Units [HQ-3 (61.1 mm diameter) Drilling]:

Drilling in HQ size (by telescoping through the PW) commenced on March 8th from a hole depth of approximately 164' (50.0m) (see Figure 8). The HW casing was reamed to 166' (50.6m) where circulation was regained following penetration of a sand zone at the base of the original PQ hole.

Following penetration of the sand zone by the HQ-3 drillstring and subsequent casing off of the sand with HW casing, drilling proceeded through the remaining Quaternary and Mesozoic deposits with only minor interruptions. No core was recovered from 167' to 172' (50.9-52.4m). The hole was advanced from 172'

to 289' (52.4-88.1m) in two shifts on March 9th. The Mesozoic/Paleozoic contact was reached at 252' (76.8m).

Paleozoic HQ-3 Drilling

Long Rapids Formation:

From a drilling viewpoint, the upper portion of the Long Rapids Formation was found to drill in a similar manner as the lower portion of the Mesozoic sediments. Based on recovered cores, the Long Rapids Formation at Onakawana consists predominantly of clays with some shale interbeds.

Drilling was stopped at 374' (114m) where the drill encountered sufficiently competent shale to cement the HW casing. This was done before advancing further into the bedrock.

Cementing the HW Casing:

HQ-3 drilling was suspended on March 12th, and reaming of the HW casing began immediately (see Figure 8). Some difficulty was experienced in getting the HW casing moving, probably due to sanding and/or squeezing. Following reaming of the casing to the base of the hole at 374' (114m), the hole was flushed with clean water. Cementing of the casing was accomplished with 12 gallons (54.5 litres) of cement slurry (with calcium chloride added to accelerate setting time) which was pumped down the hole followed by clean water. The cement was allowed to set for about 12 hours.

The HQ rods were then lowered with a 2' (0.6m) starting barrel to a depth of 370' (112.8m) where the cement fully

supported the weight of the rods (about 28,0001b - 12,700kg). The cement slurry remaining in the hole was washed out using an open 2' (0.6m) barrel and then on March 13th, a packing box and mud return line were installed at the top of the HW casing string. The drilling of the balance of the Long Rapids Formation below the cemented-in-casing to 374' (114m) was completed by the end of the day shift on March 14th.

Williams Island Formation HQ-3 Drilling:

The Williams Island Formation extends from 512' to 821.5' (156.1-250.4m) and consists of two members, an upper carbonate member and a lower shale member. The contact between the upper member of the Williams Island Formation and the overlying Long Rapids Formation was encountered on March 14th. Drilling through the Williams Island Formation was completed on March 19th.

When drilling between the depths of 552' to 562' (168.2-171.3m), all mud circulation was lost. By use of "kwik seal" and conditioning the hole in an attempt to build-up a mud wall, partial circulation was regained. HQ-3 drilling then resumed with an estimated 50-75 % mud return and good core recovery. The mud recovery tank was drained and cleaned regularly to avoid excessive accumulations of cuttings.

Murray Island Formation HQ-3 Drilling:

The Murray Island Formation was intersected at a depth 821.5' (250.4m) through to 872' (265.8m). The unit, consisting

predominantly of light brown, fossiliferous limestone with some brecciation at the base of the unit, required large amounts of fluid during drilling. Drilling through this formation was completed on March 19th.

Moose River Formation HQ-3 Drilling:

The Moose River Formation in the Onakawana B Drillhole consists of unfossiliferous to poorly fossiliferous limestone, dolostone, brecciated carbonates, gypsum and minor anhydrite. It was intersected at depths 872' through to 1029.5' (265.8-313.8m). Drilling through this formation took place from March 19-21st. No major problems were encountered within this interval.

Precambrian HQ-3 Drilling:

The Precambrian basement rocks were encountered at a depth of 1029.5' (313.8m) and the hole was subsequently terminated on March 22nd at a depth of 1053' (321m) after penetrating 23.5' (7.2m) of weathered granitic gneiss. No difficulties were encountered drilling this interval.

Rod Pull-out and Cementing:

Following completion of drilling, the rods and HQ-3 core barrel were pulled out of the hole. A cementing program was then implemented.

The open HQ rods were then lowered to approximately 16' (4.9m) off the bottom of the hole and a bottom cement grout plug

was pumped down the rods. The rods were then pulled back to approximately 500' (152.4m) and the second cement plug was pumped down the rods. The bottom plug cemented the hole over the bottom 100' (30.5m) of the hole. The second cement plug filled the hole from approximately 500' (152.4m) up to approximately 350' (106.7m).

Immediately following installation of the middle cement plug, the HW casing below the 340' (103.6m) depth was cut off (i.e. the lowest 35' (10.7m) of the casing). The cut was successfully made and the HW casing above the 340' (103.6m) was removed.

An attempt was made to remove 120' (36.6m) of the PW casing remaining in the hole. Water was pumped down the hole while the drill was used, in an attempt to rotate or move the casing. This procedure continued for 2 hours without success. Following this attempt, the casing hammer was connected to the winch cable and an attempt was made to drive or pull the PW casing. After 2 hours of hammering the PW casing, it had moved less than 2" (5.1cm) with no indication of any loosening in the hole. At this point it was decided to leave the PW casing in the hole.

The upper or third cement plug was then installed in accordance with requirements of the Petroleum Resources Act (Ministry of Natural Resources). This cement plug, which was to extend from 50'(15.2m) below to the surface, was found to have settled an estimated 25' (7.6m) after initial cementing. Pulling the casing and the final cementing of the hole to surface was completed on March 23rd.

APPENDIX D
ONAKAWANA B DRILLHOLE CONODONT SAMPLES

Identification of conodonts in samples COB-1 to COB-11 was carried out by Dr. T.T. Uyeno (Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, Calgary). Identifications of conodont species and assignments to assemblage zones for samples COB-12 to COB-36 were carried out by staff of the OGS and should be considered as tentative only. Samples are listed by number rather than drillcore interval to avoid mixing the two sets of identifications.

Sample # and depth:	Conodonts:
COB-1: 114-124 cm below the Upper Devonian/Cretaceous contact is at 252'(76.8m)	barren
COB-2: 360'4"-360'10" (109.8-110m)	*Palmatolepis quadrantinodosalobata* Sannemann *P. glabra* Ulrich & Bassler age: Upper *crepida* to Lower *rhomboidea* Zones
COB-3: 399'-399'8" (121.6-121.8m)	shale bedding plane
COB-4: 402'1"-402'10" (122.6-122.8m)	*Palmatolepis triangularis* Sannemann *P. quadrantinodosalobata* Sannemann *P. subperlobata* Branson & Mehl age: Lower *triangularis* to Lower *crepida*? Zones
COB-5: 405'7"-406'3" (123.6-123.8m)	shale bedding plane

COB-6: 424'10"-425'8" (129.5-129.7m)	*Palmatolepis unicornis* Miller & Youngquist *P. subrecta* Miller & Youngquist *Polygnathus webbi* Stauffer *P.* cf. *P. normalis* Miller & Youngquist age: Lower to Upper *gigas* Zones
COB-7: 438'6"-439'1" (133.7-133.8m)	*Palmatolepis gigas* Miller & Youngquist *P. unicornis* Miller & Youngquist age: Lower to Upper *gigas* Zones
COB-8: 447'-447'5" (136.2-136.4m)	*Palmatolepis hassi* Muller & Muller *P. subrecta* Miller & Youngquist age: *A. triangularis* to Lower *gigas* Zones, poor Lower *gigas* in viewing COB-9
COB-9: 474'6"-475'4" (144.6-144.9m)	*Palmatolepis* cf. *P. gigas* Miller & Youngquist *P. foliacea* Youngquist age: Lower *gigas* Zone (prob.)
COB-10: 497'8"-498'8" (151.7-152m)	*Ancyrodella gigas* Youngquist *Polygnathus asymmetricus asymmetricus* Bischoff & Ziegler *Palmatolepis* sp. indet. (the only large Pa is broken) *Icriodus symmetricus* Branson & Mehl *Polygnathus* cf. *P. dubius* Hinde age: Middle *asymmetricus*?
COB-11: 525'-526' (160-160.3m)	*Ancyrodella rotundiloba rotundiloba* Bryant *Polygnathus dengleri* Bischoff & Ziegler *P. dubius* Hinde age: Lower *asymmetricus*
COB-12: 252'-252'9" (76.8-77m)	*Palmatolepis quadrantinodosa inflexoidea* Ziegler *P. perlobata* subsp. *Polygnathus* sp.

COB-13: 274'3"-275' (83.6-83.8m)	*Palmatolepis quadrantinodosa quadrantinodosa* Branson & Mehl *P. perlobata* subsp. ?*P. glabra pectinata* Ziegler *Polygnathus* sp.
COB-14: 281'5"-282'1" (85.8-86m)	*Palmatolepis glabra prima* Ziegler & Huddle *P. rhomboidea* Sannemann *Polygnathus* sp. age: *rhomboidea* Zone
COB-15: 289'3"-290' (88.2-88.4m)	*Palmatolepis glabra prima* Ziegler & Huddle ?*P. quadrantinodosa inflexa* Muller - fragment *Polygnathus* sp. age: *rhomboidea* Zone
COB-16: 306'3"-307" (93.3-93.6m)	*Palmatolepis subperlobata* Branson & Mehl *P. glabra prima* Ziegler & Huddle *P. quadrantinodosa* inflexa Muller *Polygnathus* sp. age: *rhomboidea* Zone
COB-17: 316'5"-317'1" (96.4-96.7m)	*Palmatolepis subperlobata* Branson & Mehl *P. minuta minuta* Branson & Mehl *P. glabra prima* Zeigler & Huddle *P. quadrantinodosa inflexa* Muller *P. rhomboidea* Sannemann *Polygnathus* sp. age: *rhomboidea* Zone
COB-18: 321'5"-322'1" (98-98.2m)	*Palmatolepis glabra prima* Ziegler & Huddle *P. minuta minuta* Branson & Mehl *P. quadrantinodosa inflexa* Muller *P. rhomboidea* Sannemann *Polygnathus* sp. age: *rhomboidea* Zone
COB-19: 333'1"-333'9" (101.5-101.7m)	*Palmatolepis minuta minuta* Branson & Mehl *P. subperlobata* Branson & Mehl ?*P. glabra* subsp. Ulrich & Bassler - fragment *P. rhomboidea* Sannemann age: *rhomboidea* Zone

COB-20: 347'-347'2" (105.76-105.82m) and 347'8"-348'3" (106-106.1m)	*Palmatolepis minuta minuta* Branson & Mehl *P. glabra prima* Ziegler & Huddle *P. subperlobata* Branson & Mehl *Ancyrognathus* sp. *Polygnathus* sp. age: Lower *rhomboidea* - Upper *crepida* Zones
COB-21: 367'6"-368' (112-112.2m)	*Palmatolepis quadrantinodosa-lobata* Sannemann ?*Mesotaxis* sp. age: Upper *crepida* Zone
COB-22: 379'-379'6" (115.5-115.7m)	*Palmatolepis tenuipunctata* Sannemann *P. perlobata perlobata* Ulrich & Bassler *P. crepida* Sannemann *P. quadrantinodosa inflexa* Muller *P.* sp. *Mesotaxis* sp. *Polygnathus* sp. *Ancyrognathus* sp. age: Upper *crepida* Zone
COB-23: 389'-389'6" (118.6-118.7m)	*Palmatolepis subperlobata* Branson & Mehl *P.* cf. *regularis* Bond *P. rhomboidea* Sannemann *P.* sp. *Icriodus* sp. *Polygnathus* sp. age: Upper *crepida* Zone
COB-24: 395'-395'6" (120.4-120.5m)	*Palmatolepis triangularis* Sannemann *P. subperlobata* Branson & Mehl *Polygnathus* sp. age: *P. triangularis* Zone
COB-25: 410'-410'6" (125-125.1m)	*Palmatolepis subperlobata* Branson & Mehl *Icriodus* sp. *Polygnathus* sp.
COB-26: 415'-415'6" (126.5-126.6m)	*Palmatolepis subperlobata* Branson & Mehl *Polygnathus* sp.

COB-27:	419'4"-419'10" (127.8-128m)	*Palmatolepis linguiformis* Muller *P. hassi* Muller *P. subrecta* Miller & Youngquist (?juvenile-no lateral flange) *Polygnathus* sp. age: Upper *gigas* Zone
COB-28:	430'6"-431' (131.2-131.4m)	*Palmatolepis linguiformis* Muller *P. subrecta* Miller & Youngquist *P. gigas* Miller & Youngquist *Ancyrodella* sp. *Polygnathus* sp. age: Upper *gigas* Zone
COB-29:	483'-483'6" (147.2-147.4m)	*Palmatolepis gigas* Miller & Youngquist *P. unicornis* Miller & Youngquist *P. foliacea* Youngquist *P. hassi* Muller ?*P. subrecta* Miller & Youngquist - juvenile age: Lower *gigas* Zone
COB-30:	490'3"-490'9" (149.4-149.6m)	*Palmatolepis unicornis* Miller & Youngquist *Palmatolepis gigas* Miller & Youngquist *Icriodus* sp. *Polygnathus* sp. age: *A. triangularis* Zone
COB-31:	510'-510'6" (155.4-155.4m)	*Polygnathus asymmetricus* *asymmetricus* Bischoff & Ziegler *Polygnathus* sp. *Ancyrodella* sp. age: *asymmetricus* Zone
COB-32:	515'6"-516' (157.1-157.3m)	*Polygnathus aysmmetricus* *asymmetricus* Bischoff & Ziegler *Ancyrodella* sp. *Polygnathus* sp. *Icriodus* sp. age: *asymmetricus* Zone
COB-33:	528'8"-529' (161.1-161.2m)	*Polygnathus* sp. *Icriodus* sp.
COB-34:	548'6"-549' (167.2-167.3m)	barren

COB-35:	555'-555'6" (169.2-169.3m)	barren
COB-36:	571'-571'6" (174-174.2m)	barren

APPENDIX E
TOTAL ORGANIC CARBON CONTENT (TOC) VALUES FROM THE LONG RAPIDS FORMATION INTERVAL
Onakawana B Drillhole

[Samples for analyses were collected by R.Bezys in 1985 and subsequently analysed at McMaster University's geochemistry laboratory (Hamilton, Ontario) with a LECO carbon determinator by O.Mudroch].

Sample #	Depth (m)	TOC %
OX-63	153.2	4.39
OX-64	150.4	5.69
OX-65	139.5	3.51
OX-66	135.6	3.45
OX-67	128.8	3.96
OX-68	127.7	4.33
OX-69	126.7	4.81
OX-70	124.9	5.72
OX-71	125.4	5.28
OX-72	122.7	5.28
OX-73	119.8	5.25
OX-74	118.7	5.50
OX-75	114.8	3.39
OX-76	112.8	2.83
OX-77	107.6	4.80
OX-78	105.5	1.89
OX-79	102.9	4.48
OX-80	102.8	4.99
OX-81	101.4	4.72
OX-82	92.2	0.42

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53°

84°

82°

80°

52°

51°

LEGEND

Mesozoic

9 Mattagami Fm.

Devonian

8 Long Rapids Fm.

7 Williams Island Fm.

6 Murray Island Fm.

5 Moose River Fm.

4 Kwatabohegan Fm.

3 Stooping River Fm.

2 Sextant Fm.

1 Kenogami River Fm.

PreDev. Pre-Devonian rocks

PreC Precambrian rocks

Ontario Northland Railway

Scale

0 12 24 36

Km

Paleozoic/Precambrian Boundary

Attawapiskat River

Kapiskau River

Albany River

PreDev.

JAMES

BAY

Moosonee

Moose Factory

Moose River

Cheepash River

Harricanaw River

84°

82°

80°

53°

52°

51°

LEGEND

oic

Mattagami Fm.

an

Long Rapids Fm.

Williams Island Fm.

Murray Island Fm.

Moose River Fm.

Kwatabohegan Fm.

Stooping River Fm.

Sextant Fm.

Kenogami River Fm.

Pre-Devonian rocks

Precambrian rocks

Ontario Northland Railway

Scale

12 24 36

Km

Paleozoic/Precambrian Boundary

Attawapiskat River

Kapiskau River

Albany River

PreDev.

JAMES

BAY

1

3

4

5

6

7

Moosonee

Moose Factory

Moose River

Cheepash River

Harricanaw River

2

2 Sextant Fm.

1 Kenogami River Fm.

PreDev. Pre-Devonian rocks

PreC Precambrian rocks

+++ Ontario Northland Railway

Scale

0 12 24 36

Km

Paleozoic/Precambrian Boundary

BAY

52°

51°

50°

84°

82°

80°

ONTARIO

QUEBEC

Albany River

Kenogami River

Cheepash River

Moose River

Missinaibi River

Mattagami River

Abitibi River

Hannah Bay

Moosonee

Moose Factory

Moose River Crossing

Onakawana

Schlievert Lake

Grand Rapids

Williams Island

Coral Rapids

Sextant Rapids

Harricanaw River

PreDev.

PreC

1 3 4 5 6 7 8 9

MAP 1: GEOLOGY OF THE MOOSE RIVER BASIN (MODIFIED AFTER SANFORD & NORRIS, 1975, FIG. 4)

Sextant Fm.

Kenogami River Fm.

Pre-Devonian rocks

Precambrian rocks

Ontario Northland Railway

Scale

12 24 36

Km

Paleozoic/Precambrian Boundary

BAY

52°

51°

50°

84°

82°

80°

ONTARIO

QUEBEC

Albany River

Albany River

Kenogami River

Cheepash River

Moose River

Harricanaw River

Missinaibi River

Mattagami River

Abitibi

Moosonee

Moose Factory

Moose River Crossing

Schlievert Lake

Onakawana

Grand Rapids

Williams Island

Coral Rapids

Sextant Rapids

PreDev.

PreC

1 3 4 5 6 7 8 9

MAP 1: GEOLOGY OF THE MOOSE RIVER BASIN (MODIFIED AFTER SANFORD & NORRIS, 1975, FIG. 4)